AGRICULTURAL ENGINEERING

OCTOBER • 1954

In this Issue . . .

Evaluating Systems and Equipment for the Artificial Drying of Grain and Corn

•

Torque-Amplifier Drive Provides Farm Tractor with Additional Travel Speeds

•

Engineers Develop More Accurate Formula to Determine Friction Loss in Aluminum Pipe

•

A Study of Methods for Estimating the Infiltration of Water into the Soil

•

New Drain-Spacing Formula for Sub-surface Drains in Irrigated Lands

ASAE Winter Meeting • Chicago, Ill., December 6 to 8

THE JOURNAL OF THE
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

CASE educational materials

Training Aids for Greater Service to Farmers

Moving Pictures

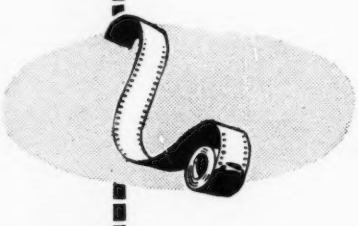
Slide Films

Booklets

Posters

Wall Charts

. . . and many others for a wide choice

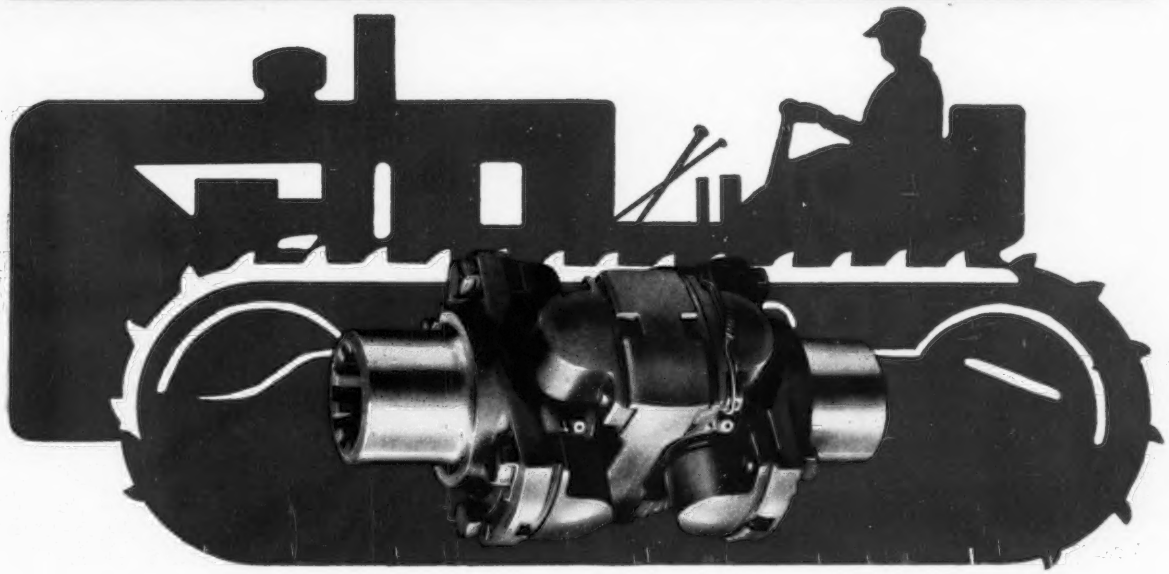


FREE CATALOG

Send for your copy now . . .

In practical farming, nothing can be truly modern until it can be done by machinery. And so the advanced farm practices sparkle with reality when shown in actual application with modern machines. Grassland farming and forage feeding . . . pond building and water spreading . . . terracing, contour tillage and strip cropping . . . seed growing and seed saving . . . soil building and farm safety—all become vivid and vital when shown in moving color or by clear-cut chart. Send for "Visual Aids to Modern Farming" . . . see the scope of subjects covered . . . Let Case lighten your load of leadership. J. I. Case Co., Racine, Wis.

FLEXIBLE



Modern Crawler tractor design requires a F-L-E-X-I-B-L-E connection between the engine and transmission. MECHANICS Close-Coupled Type UNIVERSAL JOINTS not only provide for high angularity within cramped space but compensate for out-of-alignment conditions. The shocks and strains that crawler tractors encounter in heavy duty work often are so great that they temporarily twist the tractor frame. MECHANICS Close-Coupled Type UNIVERSAL JOINTS are designed to provide the F-L-E-X-I-B-I-L-I-T-Y needed to make efficient operation possible under such adverse conditions. MECHANICS exclusive KEY method of driving has the highest safety factor, transmits the most torque, and averts costly breakdowns that result from driving through bolts or screws that work loose. Let our engineers show you how these MECHANICS advantages will benefit your product.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner • 2046 Harrison Ave., Rockford, Ill.

MECHANICS
Roller Bearing BW
UNIVERSAL JOINTS

For Cars • Trucks • Tractors • Farm Implements • Road Machinery • Aircraft • Tanks • Busses and Industrial Equipment

AGRICULTURAL ENGINEERING

Established 1920

CONTENTS • OCTOBER, 1954 • Vol. 35, No. 10

Heat Required to Vaporize Moisture 705
H. K. Johnson and A. C. Dale

Farm Tractor with Torque-Amplifier Drive 710
Henry A. Ferguson

Friction Loss in Aluminum Pipe 715
Harold E. Gray, Gilbert Levine and M. Bogema

Practical Aspects of Draintile Durability 717
P. W. Manson and D. G. Miller

Estimating Infiltration 719
D. B. Krimgold and O. Beenhouwer

Drain-Spacing Formula 726
Lee D. Dumm

Some Effects of Mulch Tillage 731
F. W. Schaller and D. D. Evans

Drying Rice with Unheated Air 735
Stanton Morrison

The Two-Ball Radiometer 738
R. V. Dunkle and J. T. Gier

News Section 740

Index to Advertisers 760

Note: AGRICULTURAL ENGINEERING is regularly indexed by Engineering Index and by Agricultural Index. Volumes of AGRICULTURAL ENGINEERING, in microfilm form, are available (beginning with Vol. 32, 1951), and inquiries concerning purchase should be directed to University Microfilms, 313 N. First St., Ann Arbor, Michigan.

OFFICERS AND COUNCIL
American Society of Agricultural Engineers

George B. Nutt, President

Vice-Presidents
H. H. Beaty J. W. Martin
L. H. Skromme

Councilors
R. K. Frevert Harry Dearing, Jr.
H. N. Stapleton

Past-Presidents
E. W. Tanquary Ivan D. Wood

HEADQUARTERS STAFF
St. Joseph, Michigan

Frank B. Lanham, Secretary Ralph A. Palmer, Assistant Secretary
Raymond Olney, Treasurer

AGRICULTURAL ENGINEERING is owned and published monthly by the American Society of Agricultural Engineers. Editorial, subscription and advertising departments are at the executive office of the Society, 505 Pleasant St., St. Joseph, Mich. (Telephone: YUkon 3-2700).

RAYMOND OLNEY
Editor and Publisher

ADVERTISING REPRESENTATIVES

Chicago 2:
DWIGHT EARLY & SONS
100 North LaSalle St.
Tel. CEntral 6-2184

New York 17:
BILLINGSLEA & FICKE
420 Lexington Ave.
Tel. LExington 2-3667

SUBSCRIPTION PRICE: $4.00 a year, plus an extra postage charge to all countries to which the second-class postage rate does not apply; to ASAE members anywhere, $3.00 a year. Single copies (current), 40 cents each.

POST OFFICE ENTRY: Entered as second-class matter, October 28, 1933, at the post office at Benton Harbor, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103. Act of October 3, 1917, authorized August 11, 1921.

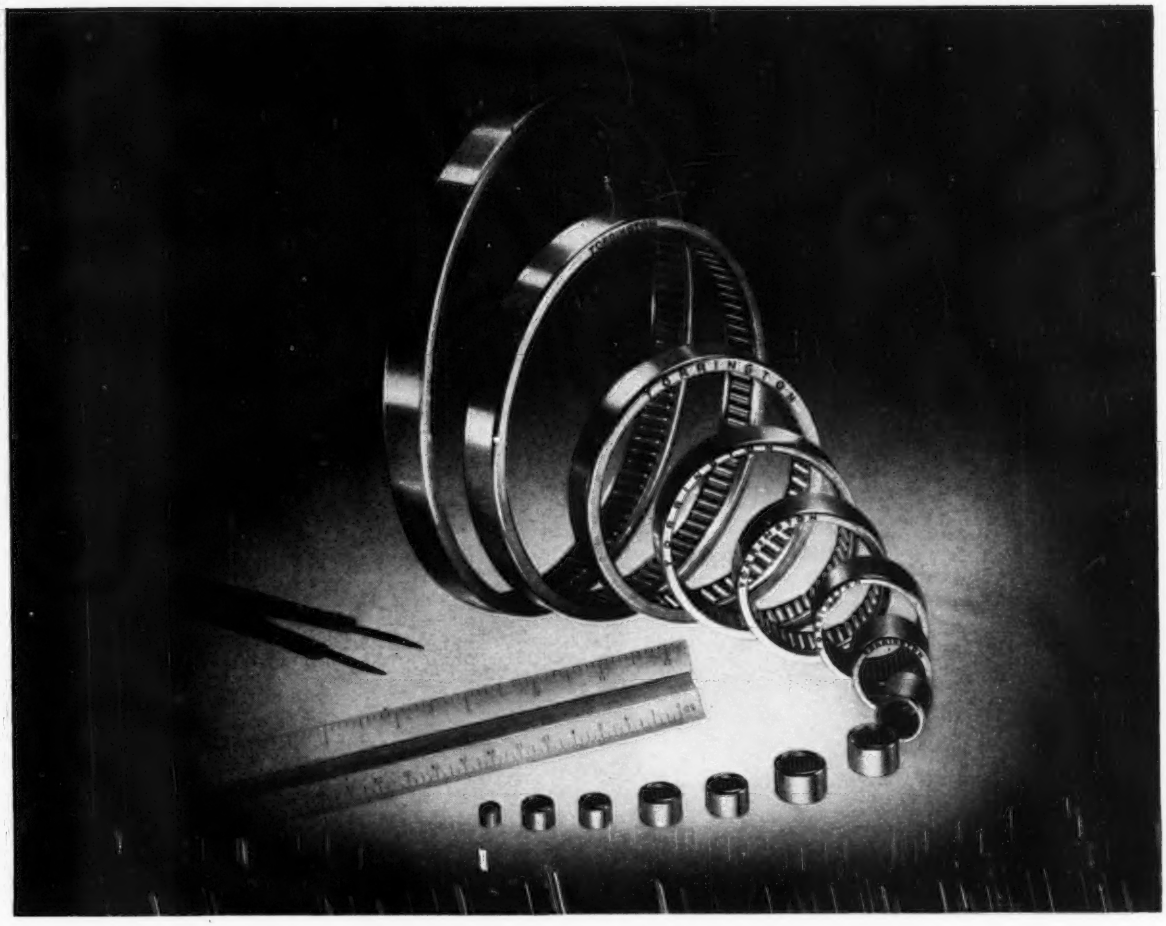
The American Society of Agricultural Engineers is not responsible for statements and opinions advanced in its meetings or printed in its publications; they represent the views of the individuals to whom they are credited and are not binding on the society as a whole.

TITLE: The title AGRICULTURAL ENGINEERING is registered in the United States Patent Office.

COPYRIGHT: Copyright, 1954, by the American Society of Agricultural Engineers.

Reprints may be made from this publication on condition that full credit be given AGRICULTURAL ENGINEERING and the author, and that date of publication be stated.

AGRICULTURAL ENGINEERING is a member of the Audit Bureau of Circulations.



"Look at the range of sizes of
TORRINGTON NEEDLE BEARINGS"

The Torrington Needle Bearing is produced in a wide range of sizes—for shaft diameters from ⅛" to 7¼"—to meet the needs of the thousands of products throughout industry in which it has become standard equipment.

Whatever the size, the basic design is the same—a full complement of free running rollers, without separators or cages, retained by a thin hardened outer shell which serves as the outer race. This means a greater radial load capacity for its size than any other anti-friction bearing, plus compactness and long, maintenance-free operation.

Several widths are available in each size to meet specific design requirements, and they are also made with one end closed for use over stub shafts.

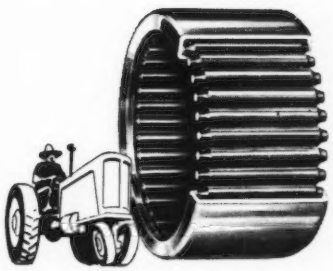
The Torrington Company has engineered thousands of different Needle Bearing applications in many industries during the bearing's 20-year history. Our Engineering Department offers the benefits of this experience in applying Needle Bearings to your products.

THE TORRINGTON COMPANY
Torrington, Conn. South Bend 21, Ind.

District Offices and Distributors in Principal Cities of United States and Canada

TORRINGTON NEEDLE BEARINGS

Needle • Spherical Roller • Tapered Roller • Cylindrical Roller • Ball • Needle Rollers



Tractors, harvesters, combines, mowers and many other farm machines produced by leading manufacturers utilize Torrington Needle Bearings to good advantage. In main drives, crankshafts, gearboxes, idler pulleys, steering gears, hydraulic pumps and a host of other assemblies, Needle Bearings take the punishing loads of daily farm use.

BCA

pre-lubricated agricultural bearings used on McCormick Harvester-Thresher save assembly time and field-servicing

Here's the new McCormick No. 141 Self-Propelled Harvester-Thresher in action. The pre-lubricated, sealed BCA Bearings keep the grease in and dust and grit out . . . cut field-servicing to a minimum and mean more acres harvested between stops.

Two types of BCA agricultural bearings—low-cost, pre-lubricated *package units*—are used on the new McCormick No. 141 Self-Propelled Harvester-Thresher. *Seven* BCA Idler Pulley Assemblies and *five* BCA Flange Bearings simplify the manufacturer's assembly problems and eliminate many of the farmer's field-servicing chores.

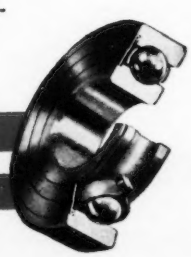
These low-cost, pre-lubricated *package units* are typical of the complete line of BCA ball bearings designed and engineered to meet the problems of both the manufacturer and user of farm equipment. They are adaptable to many agricultural applications: combines, hay balers, forage harvesters, grain elevators, corn and cotton pickers, spreaders. And BCA engineering cooperation and design assistance help solve problems involving ball bearings—that's why it will be to your advantage to bring *your* bearing problems to us.

BCA

BEARINGS COMPANY OF AMERICA

DIVISION OF FEDERAL-MOGUL CORPORATION

LANCASTER • PENNSYLVANIA



Pioneers of pre-lubricated *package unit* ball bearings for agriculture

CHECK these important differences in augers for farm machines

ONE-PIECE HELICOID FLIGHTING has greater smoothness and strength. Link-Belt also builds many different shapes in various metals to meet your specific needs—cut flight, short pitch, ribbon flight, tapering, double flight to name a few.

UNIFORM PITCH — Specialized modern machinery assures accurate forming, producing uniformity in flighting curvature.

ONLY SPECIALLY SELECTED STEELS are used to meet Link-Belt's rigid specifications — assuring smooth flight surfaces.

STRAIGHTNESS is checked before shipping and extra care is taken in handling and loading.

Complete auger for this harvester-thresher is furnished by Link-Belt. Opposed flights move cut grain to center, deliver it to pick-up conveyor.

LINK-BELT gives you sound engineering plus accuracy of manufacture for top performance

WHEN you make a Link-Belt auger part of your farm machine, you can be sure of efficient operation plus long-life, low-maintenance service. Link-Belt builds augers for every purpose—gathering cut grain back of the sickle bar, conveying, elevating, spreading, feeding, mixing or digging.

Each can be engineered for your specific requirements . . . each will provide long-lasting efficiency, thanks to Link-Belt's unequalled accuracy of manufacture. Let your nearby Link-Belt sales representative point out the many important differences in augers to you. And be sure he gives you a copy of Book 2289, covering Link-Belt's regular line of conveyor screws and components.

Typical examples of Link-Belt Augers

Sectional-flight

Helicoid flight with end, plain beater

Helicoid flight auger

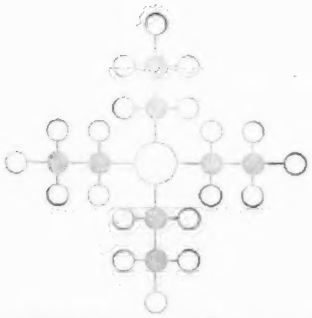
Opposed flights with center saw-tooth beater

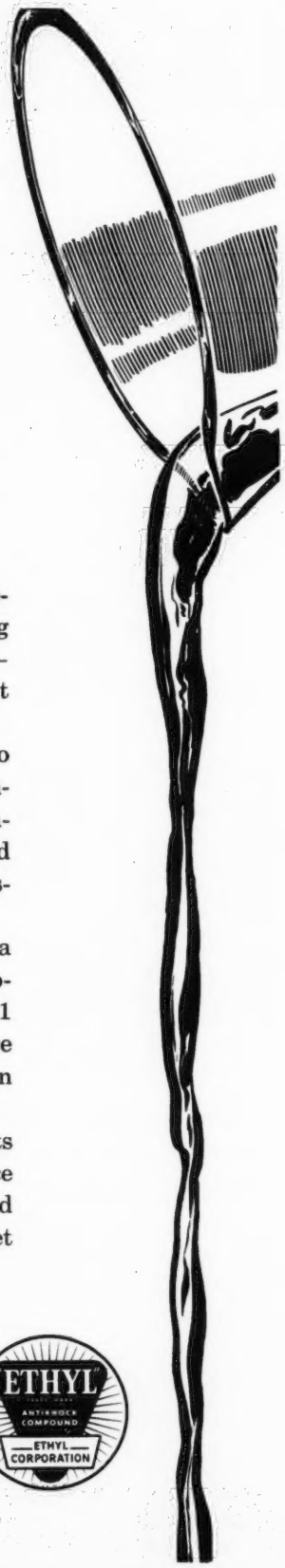
Unmounted Helicoid flighting

LINK-BELT

FARM MACHINE AUGERS

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N. S. W.; South Africa, Springs. Representatives Throughout the World. 13,384





What's the tractor fuel of the future?

Oliver Corporation engineers had this question in mind when designing their new experimental engines to study ways of boosting tractor power. The result of this work—the XO-121 engine—proved to be *the most efficient tractor engine ever built.* And it answered the question about the "fuel of the future."

The XO-121 runs on gasoline! A special gasoline . . . but by no means a trick or synthetic fuel. It's a blend of high-octane components and "Ethyl" antiknock compound. The Ethyl Corporation—which assisted in designing and testing the engine—worked out this fuel to permit the XO-121 to operate at a 12 to 1 compression ratio.

This unusually high compression ratio allows it to squeeze a greater amount of work out of this high-octane fuel . . . and produce some remarkable records. In laboratory tests the XO-121 produced 44% more power than one of today's high-performance tractor engines. It also set a new high in economy, operating on 30% less fuel than today's engine!

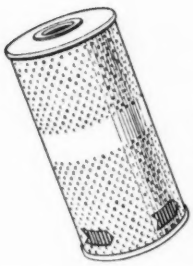
While the XO-121 will never go into production, test results clearly point the way toward a new era in tractor performance for American farmers. It shows that gasoline offers an unmatched power potential—coupled with true economy—ready to meet farmers' demands for better tractor power in the future.

The tractor fuel of tomorrow is already here—gasoline!

ETHYL CORPORATION

NEW YORK 17, N. Y.

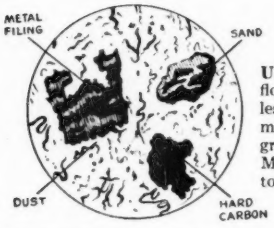
ETHYL ANTIKNOCK COMPOUND ETHYL CORPORATION



1.

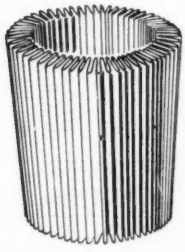
High full-flow rates within practical design dimensions: Purolator's famous "accordion-pleated" Micronic* filter element has up to ten times more filtering area than old-style filters—gives high flow rates in a minimum of space.

2.



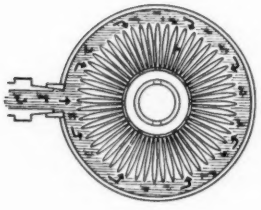
Ultra-micronic filtration: High flow rates are, of course, meaningless unless effective filtration is maintained, too. Electron micrographs prove that the Purolator Micronic filter stops particles down to *submicrons*—.0000039 in.!

3.



Maximum dirt storage capacity: The pleated design of the Purolator Micronic filter element provides many times more dirt storage space than old-style filters. This important advantage means uniform, efficient performance throughout a long service life.

4.



Minimum pressure drop: With its larger filtering area, the Purolator Micronic filter element introduces a remarkably small pressure drop into the lubricating system . . . permitting pumps of practical size and simple type.

Here's why more

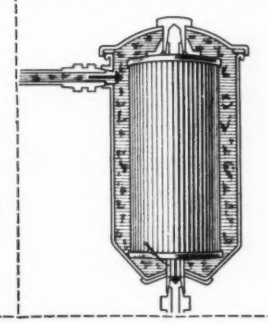
Original Equipment Manufacturers

prefer Purolator filters for *full flow*

Inch for inch and pound for pound, Purolator filters can't be beat. Test after test conducted by leading internal combustion equipment manufacturers prove that Purolator filters give finer, more dependable filtration at optimum flow rates, in minimum space.

Purolators are available in hundreds of different types, for all filter applications, including air, gasoline, lube oil, fuel oil, hydraulic fluids and water. Purolator's engineering staff and research laboratories, *the world's largest*, will be glad to assist you with any filter problem you may have.

Get the latest technical information on Purolator filters. Simply mail in the coupon below.



5.

Will not remove or absorb additives: With Purolator Micronic filtration, you keep *all* the oil quality you pay for. The Micronic filter element will not strip additives . . . an important advantage with HD and heat-resistant oils.

*Reg. U. S. Pat. Off.

PUROLATOR PRODUCTS, INC.
Rahway, New Jersey, and Toronto, Ontario, Canada
Factory Branch Offices: Chicago, Detroit, Los Angeles

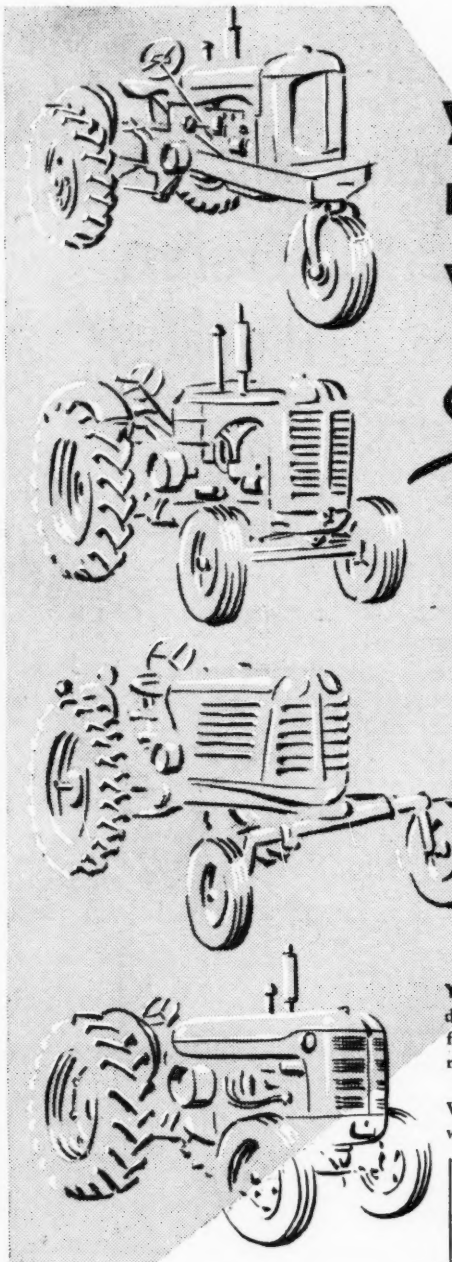
PUROLATOR
WORLD'S FINEST OIL FILTER

Purolator Products, Inc., Rahway, N. J.
Send the following Purolator catalogs:
☐ Industrial ☐ Aviation ☐ Automotive ☐ Fleet

Name_____ Title_____

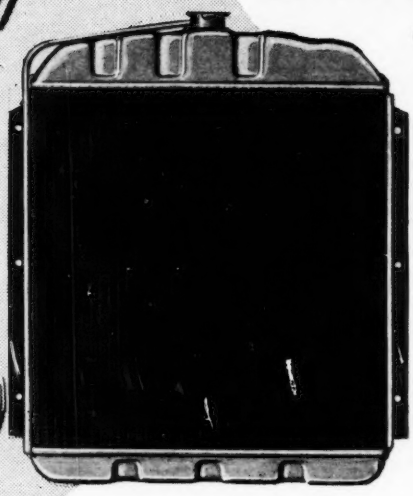
Company_____

Address_____



you get more than cooling when you...

Specify YOUNG



- LONG-LIFE RADIATORS —Built to last the life of the tractor.
- RUGGED CONSTRUCTION—in either sheet metal, cast iron or welded steel.
- TROUBLE-FREE SERVICE —Industry-proved Radiators with choice of stationary, removable one-piece, or removable section cores.
- USER SATISFACTION— Young Radiator dependability helps build product preference.

Young specialized Radiator design offers many extra advantages desired by leading tractor manufacturers. You get sturdy stiffening features for longer radiator life . . . vibration control mountings . . . restraining core side baffles . . . corner web reinforcing . . . and many others.

Whatever your tractor cooling problem may be, always specify Young. We invite your inquiry . . . without obligation. For complete information write Young Radiator Company, Racine, Wisconsin.

COOLING EQUIPMENT FOR

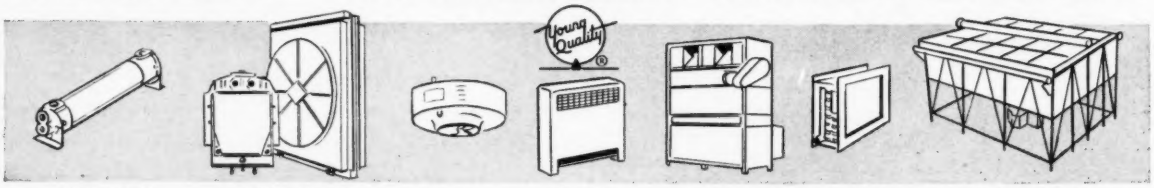
Farm Tractors	Hammer Mills	Sprayers
Threshers	Generator Sets	Farm Trucks
Combines	Pumps	Specialized Equipment
Garden Tractors		

Heat Transfer Products for Automotive, Agricultural, Industrial, Gas and Diesel Engine Application.

YOUNG

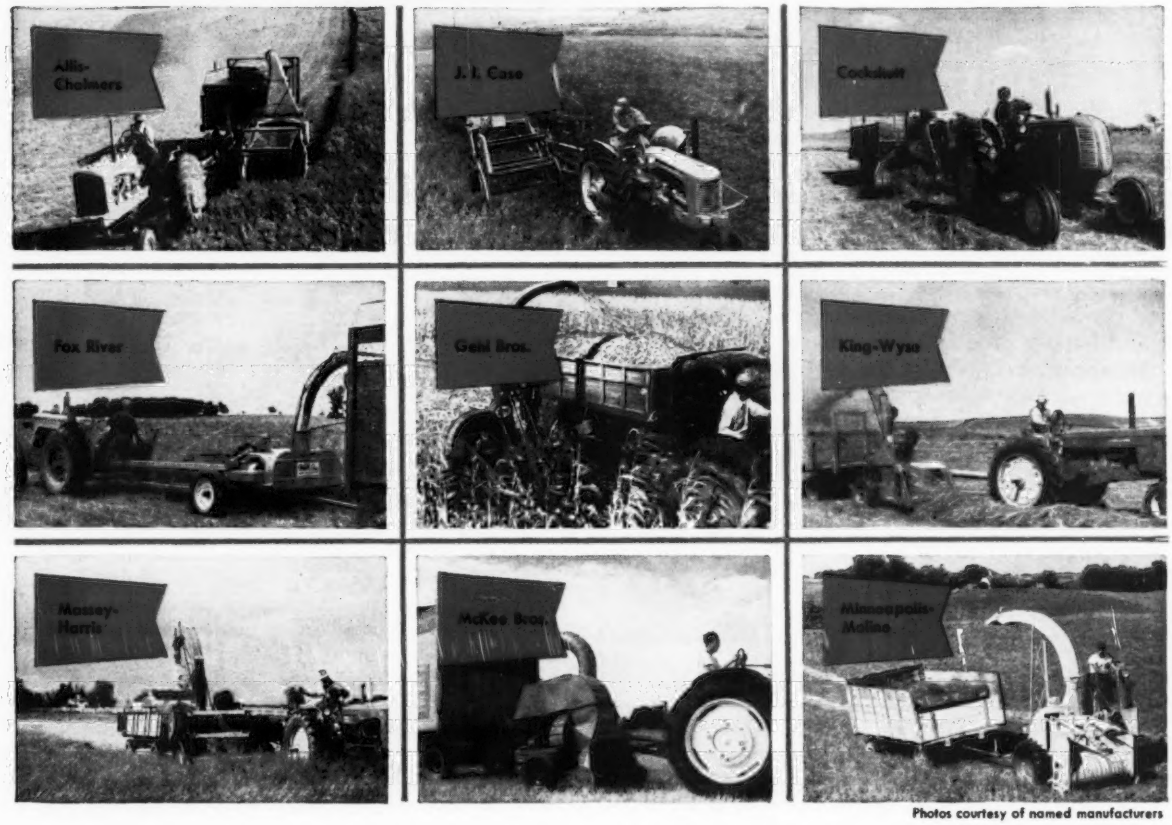
Heating, Cooling, Air Conditioning Products for Home and Industry.

YOUNG RADIATOR COMPANY DEPT. 294-K RACINE, WISCONSIN • PLANTS AT RACINE, WIS. AND MATTOON, ILL.



Shell and Tube Heat Exchangers | Automotive and Industrial Radiators | Unit Heaters | Convector Radiators | "YAC" Air Conditioners | Heating and Cooling Coils | "HC" Cooling and Condensing Units

BLOOD BROTHERS Universal Joints...



Photos courtesy of named manufacturers

chosen for forage harvesters by eighteen famous names!

To earn and hold this "majority approval," Blood Brothers Universal Joints and Drive Lines *must* be right for the job. And they *are!*

To make certain, Blood Brothers' engineers work closely with the manufacturers of forage harvesters . . . and innumerable other kinds of farm implements. Knowing the power transmission problems of the field helps Blood Brothers excel in building joints that farmers favor . . . for dependable, long-lived operation.

If your implements are not getting the advantages of Blood Brothers' performance and prestige, write for full information.

FOR FARM IMPLEMENTS, MORE BLOOD BROTHERS UNIVERSAL JOINTS ARE USED THAN ALL OTHER MAKES COMBINED.

BLOOD BROTHERS machine division

Rockwell Spring and Axle Company

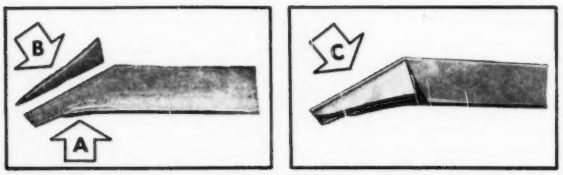
ALLEGAN, MICHIGAN

A report to you about the TEAMWORK of men and machines that helps maintain International Harvester leadership

How automatic arc welding puts uniformly high quality into IH plowshares

In this age of modern science and research, it is significant that the plowshare—one of the oldest parts in farm equipment manufacture—is still being improved.

At International Harvester, research engineers and factory production men have teamed together to apply successfully the techniques of modern automatic arc welding to mass production assembly of plowshares. The result is a consistently uniform, high-quality product that always fits right, holds its shape, wears well, and enables the farmer to do a first-rate job of plowing.



Before welding (left), the plowshare blade (A) and gunnel (B) look like this. After being automatically arc welded (right), the two parts are joined like this (C), with a strong, consistently uniform weld. Shares are forged and heat treated after welding to give them proper shape and wearing qualities.

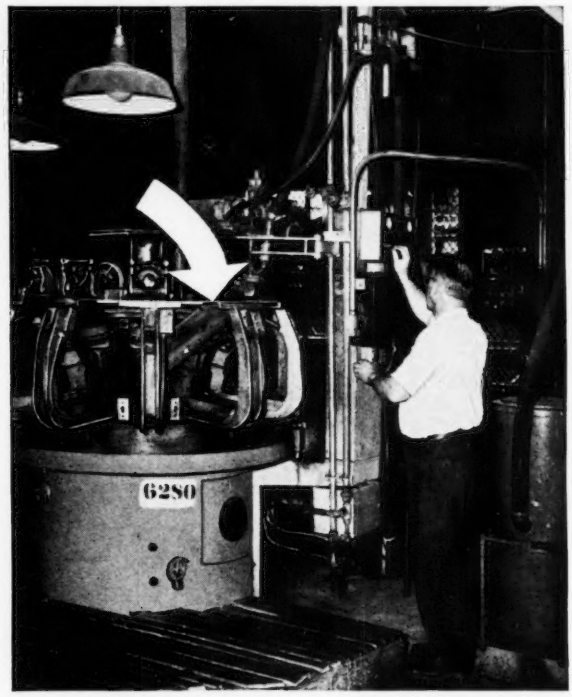
●

The common goal of IH research, design, metallurgy, field test engineering, and manufacturing is to improve the quality and performance of IH products, while keeping costs to a minimum. The result is product leadership that helps farmers everywhere reduce production costs and increase profits.

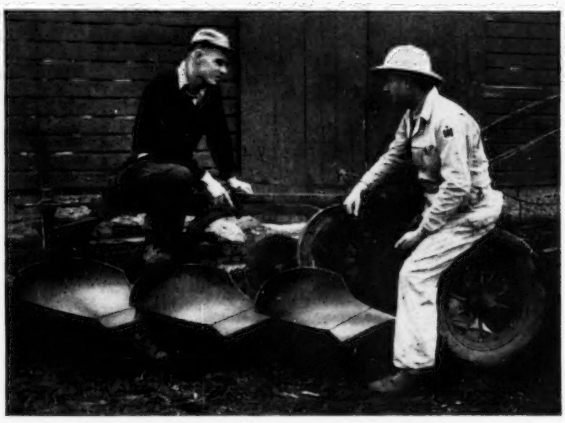
For more details, write for free engineering paper, "Automatic Arc Welding of IH Farm Equipment Parts." There is no obligation. Send postcard with your name and address to International Harvester Company, P. O. Box 7333, Chicago 80, Illinois.

INTERNATIONAL HARVESTER

International Harvester products pay for themselves in use—McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers—General Office, Chicago 1, Ill.



After successful, coordinated development work between researchers and production men in the technique of application, the automatic submerged arc welding process is now a standard factory operation at IH's Canton, Illinois, Works in the mass production assembly of plowshares. This turret-type welding fixture has 10 "stations" where 10 plowshares at a time are automatically in process of being loaded into the fixture, welded, cleaned and unloaded. Arrow points to plowshare in position in one of the "stations." In this process, a carefully engineered combination of granular flux and welding wire is used to produce, rapidly, a uniformly strong weld—*automatically.*



Both IH customers and dealers benefit from the use of automatically arc welded plowshares. Consistently uniform quality in manufacture helps assure dependable performance in the field. This is one reason why McCormick® plows are first in favor with particular plowmen everywhere.

TAKE THEIR WORD FOR IT!

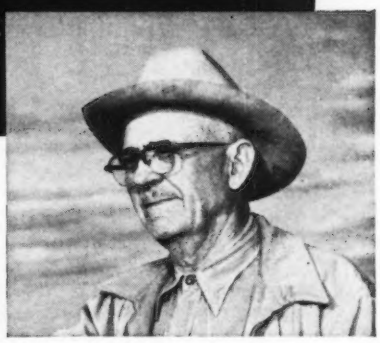
PRESSURE-CREOSOTED Fence Posts save money

Boyce Tiser, *Cleveland, Mississippi,* says:

"About 6 years ago we started replacing our old, untreated fence posts with Pressure-Creosoted Posts. I like the good-looking appearance of a fence made with Pressure-Creosoted Posts, and, of course, they are much easier to install and the fence wire goes on more easily. We've also used Pressure-Creosoted Lumber and Poles in pole barns, tractor sheds, and other buildings. There has been no sign of deterioration or decay."

J. C. Baber, *Manager of Alpine Farms, Natural Bridge Station, Virginia,* says:

"Until recently we have been using untreated locust and pine posts, which have proven most unsatisfactory in service and upkeep. Therefore, we are converting all our fencing to the use of Pressure-Creosoted Posts. We feel assured these posts will last us 40 to 50 years, which will result in considerable savings."



James S. Kreycik, *of Wood Lake, Nebraska,* says:

"Twenty-one years ago we purchased our first Pressure-Creosoted Fence Posts. We like them because they're long-lasting and highly fire-resistant, and they make a strong, straight, good-looking fence. We're replacing untreated posts with Pressure-Creosoted Posts at the rate of about 2000 a year; eventually we will have over 60 miles of boundary and cross fences using Pressure-Creosoted Posts."

THE men who are using them are the men best qualified to talk about the advantages of Pressure-Creosoted Fence Posts. And hundreds of farmers have told us they can build a longer-lasting, better-looking fence with Pressure-Creosoted Posts than with any other wood posts on the market today.

Pressure-Creosoting is a carefully-controlled, engineered operation where exactly the right amount of Creosote is forced deep into the wood to give the post maximum protection against the natural enemies of wood. And the posts used for Pressure-Creosoting are carefully selected for uniformity, straightness and ease of erection.

You can recommend Pressure-Creosoted Fence Posts without hesitation as the most economical wood posts that can be used. The small extra cost of Pressure-Creosoting is repaid time and again in extra life and savings in labor.

Many leading wood-treating plants use U·S·S Creosote in their wood treating operations. When fence posts—or any other type of farm lumber—are treated with U·S·S Creosote, you can be sure a quality product has been used.

• • •

UNITED STATES STEEL CORPORATION

525 William Penn Place • Pittsburgh 30, Pa.

Free guide to better fencing

If you would like more information on approved methods of fence construction with Pressure-Creosoted Posts, send for our guide "Fences That Pay." If, after examining it, you would like additional copies for your educational program, they will be supplied without charge. Use the coupon.

Agricultural Extension Section
United States Steel Corporation
Room 4445, 525 William Penn Place
Pittsburgh 30, Pa.

□ Please send me your new guide, "Fences That Pay."

□ Also, I would like to know the name of my nearest Pressure-Creosoted Fence Post Supplier. No obligation, of course.

Name .....

Address ..... Town .....

County ..... State .....

UNITED STATES STEEL

IMPROVE efficiency..versatility..performance

DESIGN AEROQUIP HYDRAULIC ACCESSORIES INTO YOUR FARM EQUIPMENT

AEROQUIP FLEXIBLE HOSE LINES WITH DETACHABLE, REUSABLE FITTINGS withstand extreme weather conditions. They are recommended for use with hydraulic fluids, butane, propane, lubricating oils, water, fuel, and many other fluids. Aeroquip hose assemblies can be made quickly by cutting bulk hose to required length and attaching the reusable fittings. No special tools are needed.

WITH THE AEROQUIP SELF-SEALING COUPLING changing of hydraulic attachments and accessories is quick and easy because individual fluid-carrying lines may be disconnected without loss of fluid and reconnected without inclusion of air. It is the only self-sealing coupling that mates with the Aeroquip Breakaway.

THE AEROQUIP BREAKAWAY COUPLING disconnects automatically when the implement accidentally breaks away from the tractor preventing breakage of hose lines and resulting loss of hydraulic fluid. With the Breakaway, pressure and return lines between tractor and implement may be connected and disconnected instantly. Each part of the Aeroquip Breakaway is replaceable.

Your customers can buy Aeroquip replacements through farm equipment dealers everywhere.

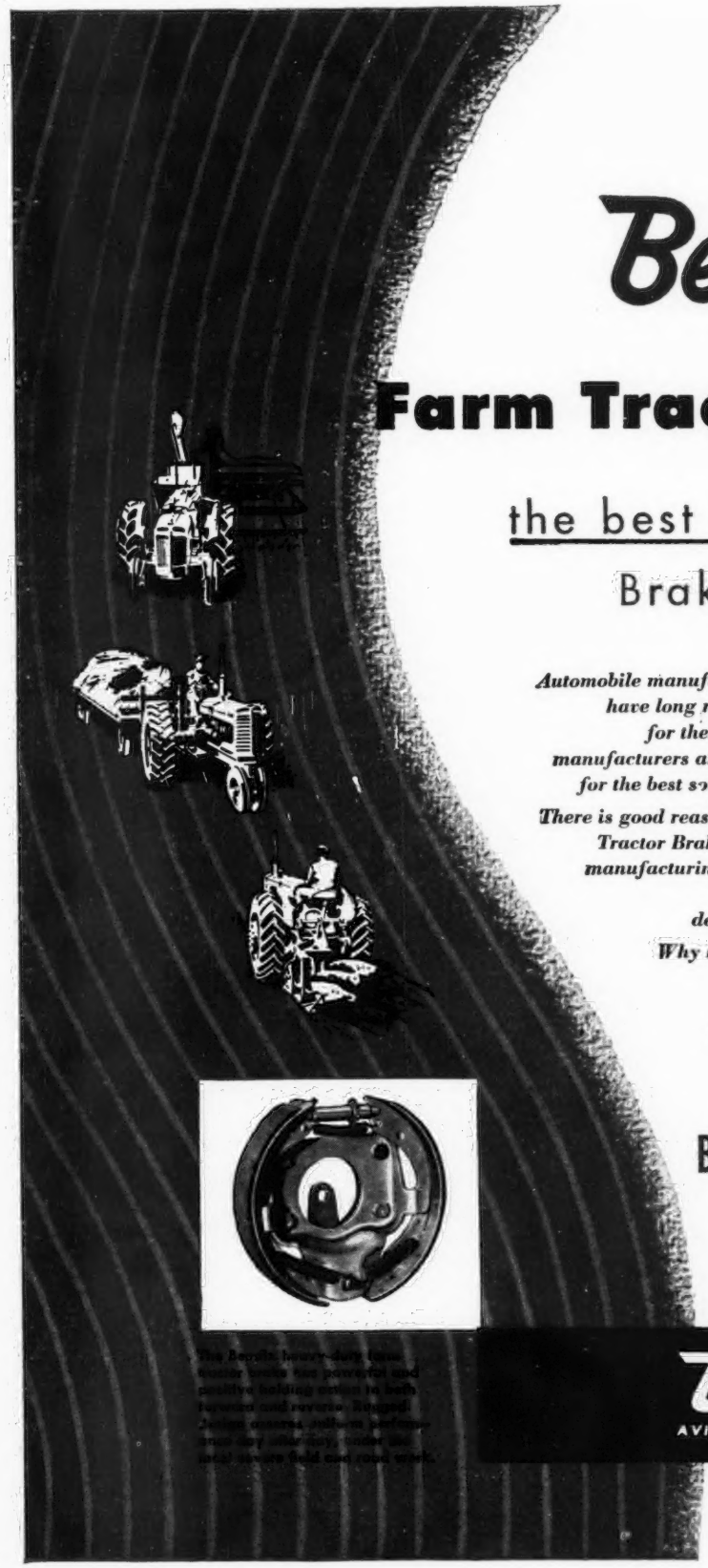
Aeroquip

REG. TRADE MARK

AEROQUIP CORPORATION, JACKSON, MICHIGAN

SALES OFFICES: Burbank, Calif. • Dayton, Ohio • Hagerstown, Md. • High Point, N. C. • Miami Springs, Fla. • Minneapolis, Minn. • Portland, Ore. • Van Wert, Ohio • Wichita, Kan.
IN CANADA: Prenco Progress and Engineering Corporation Ltd., Toronto • **IN ENGLAND:** Super Oil Seals & Gaskets, Ltd., Birmingham

AEROQUIP PRODUCTS ARE FULLY PROTECTED BY PATENTS IN U.S.A. AND ABROAD



Bendix

Farm Tractor Brakes

the best solution to every Braking Problem

Automobile manufacturers, as well as truck and bus builders, have long recognized Bendix as braking headquarters for their industries. And today progressive tractor manufacturers are turning in increasing numbers to Bendix for the best solution to their individual braking problems.

There is good reason for this growing preference for Bendix Tractor Brakes. Nowhere else can be found comparable manufacturing facilities combined with an engineering experience that cover every major braking development in the past quarter of a century.*

Why not let Bendix farm tractor brake engineers help you find the best solution to your braking problems.

Your inquiry will receive prompt attention. Write for complete information.

*REG. U.S. PAT. OFF.

BENDIX · PRODUCTS DIVISION · SOUTH BEND

EXPORT SALES

Bendix International Division, 205 East 42nd St., New York 17, N.Y. • Canadian Sales: Bendix-Eclipse of Canada, Ltd., Windsor, Ontario, Canada.

Bendix
AVIATION CORPORATION

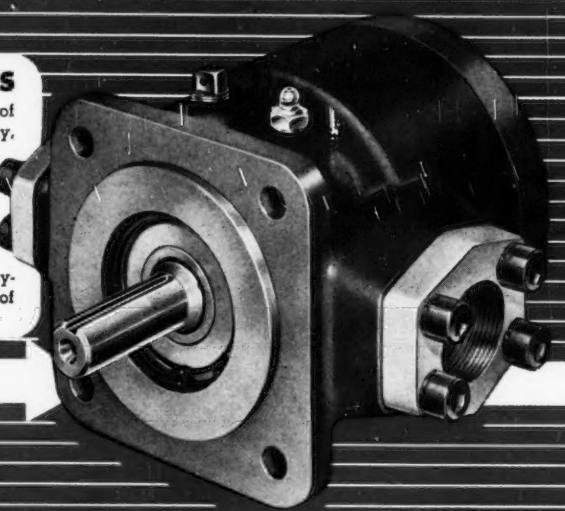
5000 PSI

FOUR COMPLETELY NEW LINES OF HYDRAULIC PUMPS WHICH GIVE YOU FAR MORE IN PERFORMANCE AT FAR LESS IN COST!

- Pumps to give new life to existing equipment . . . to improve performance, increase capacity!
- Pumps that afford the design engineer the basic equipment for entirely new concepts in hydraulically operated machines!
- Pumps for machines to do work better, quicker, cheaper!

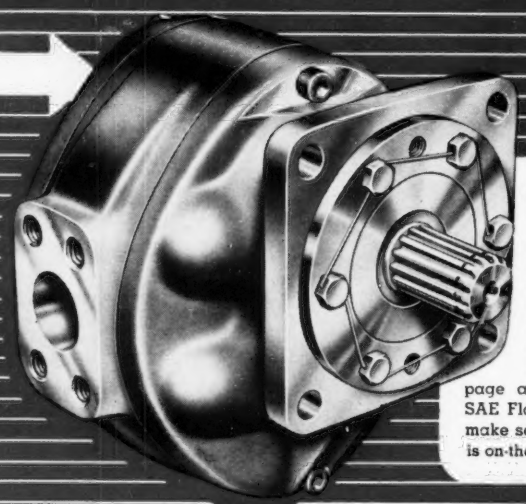
SERIES PF-100 VANE-TYPE PUMPS

DUDCO PF-100 Series Pumps can double the value of your *hydraulic dollar*. You get 2000 psi continuous duty, single-stage construction for the cost of equal capacity low pressure pumps . . . improved equipment design and increased machine efficiency without the payment of premium prices. These Pumps feature a simplified, 3-unit construction . . . the pumping cartridge incorporates the famous DUAL-VANE design which provides and assures complete balance of all hydraulic pressure loads. These Pumps have capacities of 3, 5, 8 and 11 qpm at 1200 rpm.



2000 PSI

1500 PSI

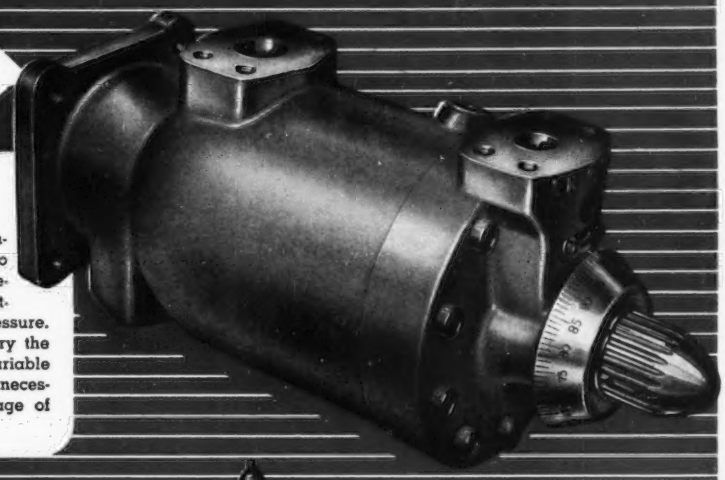


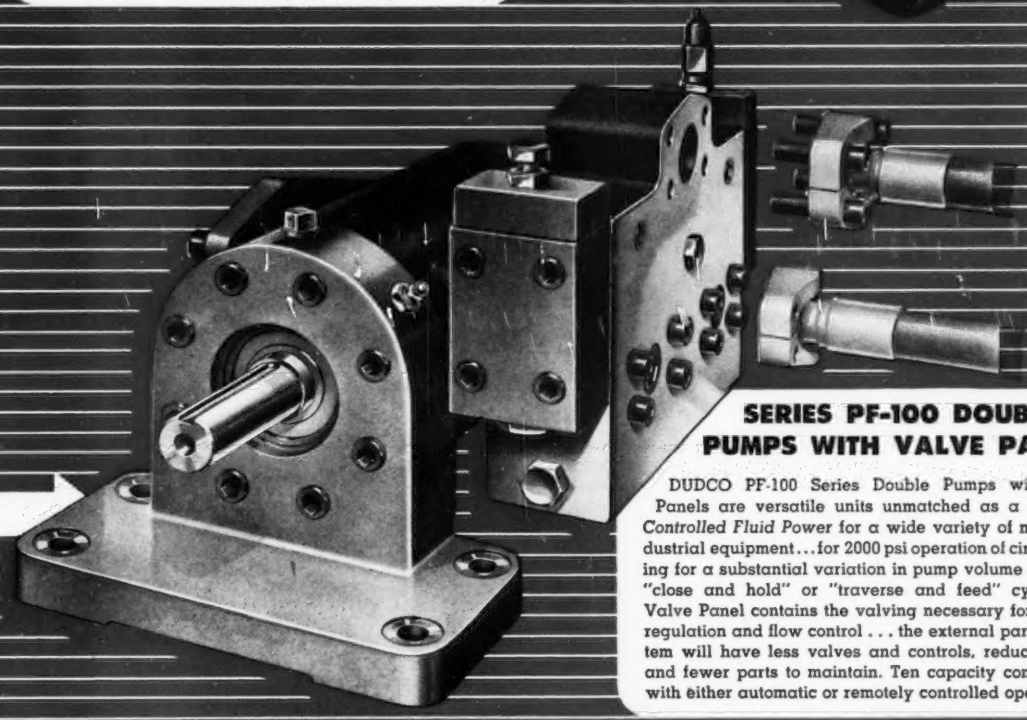
SERIES H GEAR-TYPE PUMPS

The HYDRECO Series H Pumps are intended for use in the hydraulic systems of heavy-duty mobile and industrial equipment, especially where shock loads, impact and rugged service are "normal working conditions". Four sizes (40, 50, 60, 70 gpm) deliver fluid power at 1500 psi . . . increased horsepower gives greater work output. *Pressure-Balanced* wear plates reduce oil slippage and eliminate power-robbing frictional contacts. SAE Flange Mounting and split-flange hose connections make servicing simple and reduce down-time. Equipment is on-the-job longer.

SERIES PV-600 PISTON-TYPE PUMPS

DUDCO PV-600 Series Variable Delivery Pumps generate continuous duty pressures up to 5000 psi. Two types of controls match pump output to system demands. A pressure-compensated regulator automatically varies the volume in response to system pressure. A hand wheel control enables an operator to vary the volume during the machine cycle. High pressure variable delivery means power is transmitted without the necessity for an accumulator and without any wastage of power thru a relief valve.





SERIES PF-100 DOUBLE PUMPS WITH VALVE PANELS

DUDCO PF-100 Series Double Pumps with Valve Panels are versatile units unmatched as a source of *Controlled Fluid Power* for a wide variety of modern industrial equipment...for 2000 psi operation of circuits calling for a substantial variation in pump volume as during "close and hold" or "traverse and feed" cycles. The Valve Panel contains the valving necessary for pressure regulation and flow control . . . the external part of a system will have less valves and controls, reduced piping and fewer parts to maintain. Ten capacity combinations with either automatic or remotely controlled operation.

THE NEW YORK AIR BRAKE COMPANY

1107 EAST 222nd STREET • CLEVELAND 17 • OHIO

The New York Air Brake Company
1107 East 222nd Street
Cleveland 17, Ohio

Please send details on

- ☐ SERIES PF-100 VANE-TYPE PUMPS
- ☐ SERIES H GEAR-TYPE PUMPS
- ☐ SERIES PF-100 DOUBLE PUMPS WITH VALUE PANELS
- ☐ SERIES PV-600 PISTON-TYPE PUMPS

Name_____

Address_____

City_____ Zone____ State_____

Dependable Source for Quality Rims!

For nearly half a century, leading tractor, truck and trailer manufacturers have learned to depend on The Cleveland Welding Company for high-quality, lightweight rims designed for strength and safety.

The above view shows a part of our stock of finished rims and a section of the overhead conveyor which helps to streamline our mass-production system. We can fill *your* needs for Cleve-Weld *Protecto-Tire* Rims.

Because of our economical production methods and favorable location, we are able to afford you significant advantages as your primary source for production-quality rims. May we talk it over? Write THE CLEVELAND WELDING COMPANY, W. 117th St. & Berea Rd., Cleveland 7, Ohio. (Subsidiary of American Machine & Foundry Company, New York.)

Another AMF Product

CLEVE-WELD®
PROTECTO-TIRE RIMS

Wide-Base, Depression-Type Tractor Rim

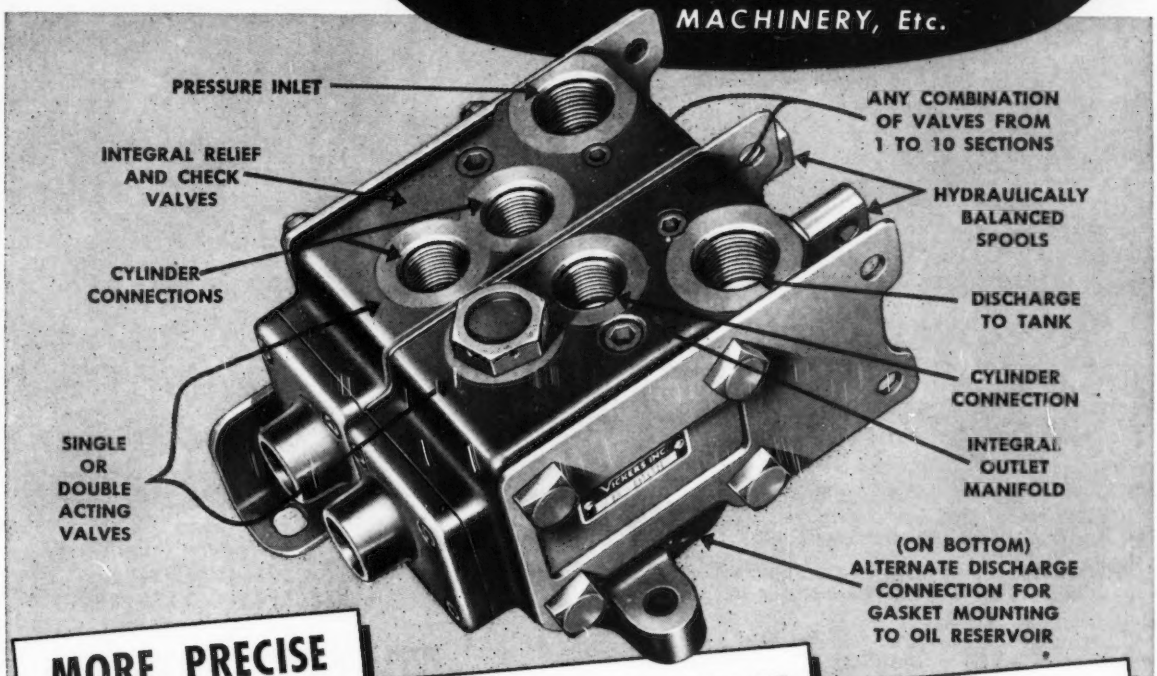
Deep-Well, Attached-Clamp Tractor Rim

Deep-Well, Drop-Center Tractor Rims

Wide-Base, Attached-Clamp Tractor Rims

NEW! Series CM11 VICKERS® MULTIPLE UNIT VALVES

For MATERIALS HANDLING EQUIPMENT, FARM TRACTORS, BUCKET LOADERS, CONSTRUCTION and MINING MACHINERY, Etc.


PRESSURE INLET
INTEGRAL RELIEF AND CHECK VALVES
CYLINDER CONNECTIONS
SINGLE OR DOUBLE ACTING VALVES
ANY COMBINATION OF VALVES FROM 1 TO 10 SECTIONS
HYDRAULICALLY BALANCED SPOOLS
DISCHARGE TO TANK
CYLINDER CONNECTION
INTEGRAL OUTLET MANIFOLD
(ON BOTTOM) ALTERNATE DISCHARGE CONNECTION FOR GASKET MOUNTING TO OIL RESERVOIR

MORE PRECISE CONTROL
Improved Metering Characteristics

REQUIRES LESS SPACE
New Combination Operating-Valve and End-Plate Sections

LOWER COST
Simplified Design and Construction

New, compact, more versatile design of valve. End sections combine in one casting the inlet or outlet manifold plate together with any operating-valve section. Inlet section also contains relief valve. Individual outlet plates available for single unit valves. Single- and double-operating valve sections can be added between end sections as needed. Valve can be adapted for tandem (series) operation. Single-acting valves available for either direction of lever shift.

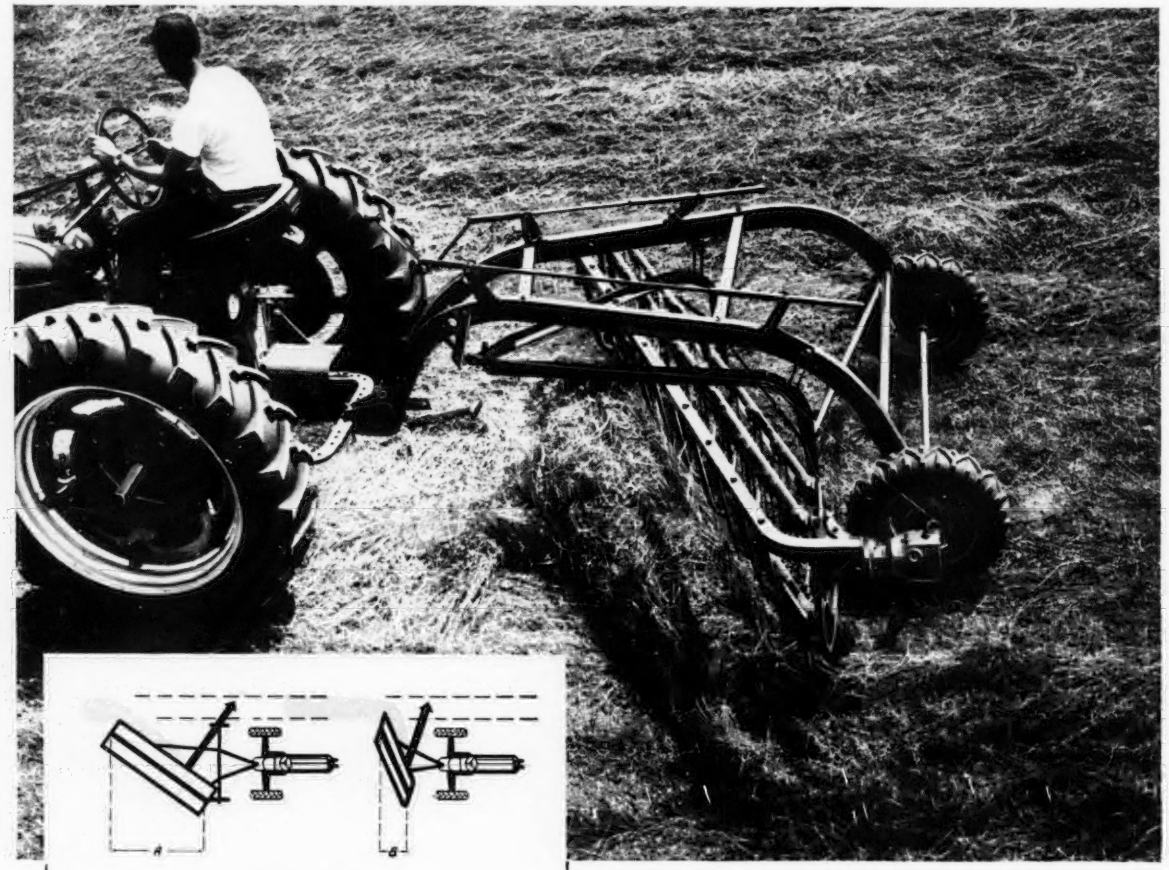
Other features include protection of pump from reverse flow during shifting . . . three point mounting for more simple installation . . . cylinder connections with ¾-16 N.F.-2 straight threads (AND 10050 type) which conform to SAE standards help insure leak-proof connections . . . optional outlet ports in end section so valve can be gasket mounted to the oil reservoir or pipe connected. Designed for use with Vickers Series V-200 Vane Pumps (up to 11 gpm), the CM11 Valve can be used up to 2000 psi working pressure. For further information write for Installation Drawing M168643.

6794

VICKERS Incorporated
DIVISION OF THE SPERRY CORPORATION
1516 OAKMAN BLVD. • DETROIT 32, MICH.

Application Engineering Offices: • ATLANTA • CHICAGO AREA (Brookfield) • CINCINNATI • CLEVELAND • DETROIT • HOUSTON LOS ANGELES AREA (El Segundo) • NEW YORK AREA (Summit, N. J.) PHILADELPHIA AREA (Media) • PITTSBURGH AREA (Mt. Lebanon) ROCHESTER • ROCKFORD • SAN FRANCISCO AREA (Berkeley) SEATTLE • TULSA • WASHINGTON • WORCESTER

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921



Conventional vs. Rolabar

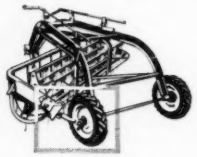
Diagram shows why conventional rakes (A) need twice as much forward motion as the new Rolabar (B) to move hay from swath to windrow. This can be demonstrated easily in the field. Less forward motion means less damage to hay, higher ground speeds.

New Rolabar Rake *gentles* hay

at ground speeds up to 8 m.p.h.!

SEVERAL years ago, New Holland engineers laid plans for new grassland machines that could match the increasing speeds of New Holland balers and improve crop quality. As a result of this program, the New Holland Rolabar Rake was introduced this year.

The New Holland Rolabar moves hay from swath to windrow in half the distance traveled by ordinary side-delivery rakes. Result? You can rake at much higher speeds without flailing the protein-bearing leaves and blossoms off the stems and into the field.



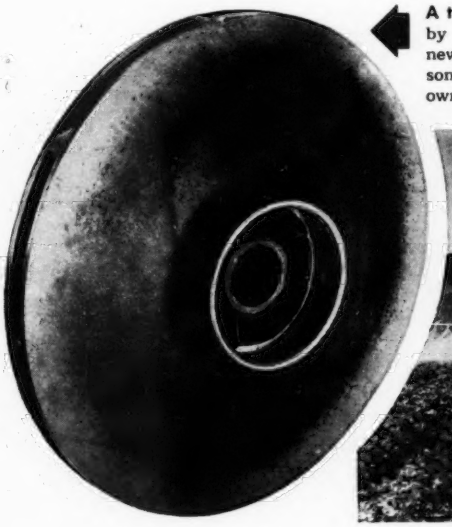
Simple, direct drive matches ground speed to rake speed

There's a big advantage to these higher speeds. By building quick-drying windrows faster, you cut curing time. Hay is ready for the baler before it can be leached by rain or bleached by too much sun. Neat, even windrows allow faster harvesting, cleaner pickup with baler or field chopper.

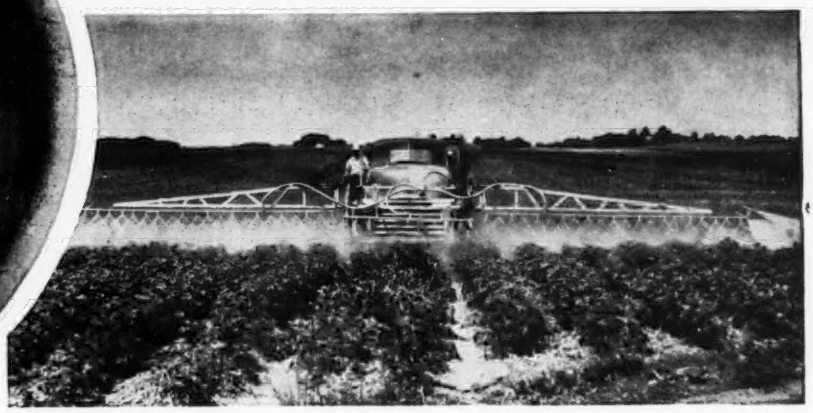
Power is delivered from the axle to an enclosed gear box by a telescoping shaft. There are no chains, pulleys or belts on this quiet-running rake.

Production of the Rolabar Rake is still another reason for New Holland's continued leadership in Grassland Farming. The New Holland Machine Co., a subsidiary of The Sperry Corporation.

NEW HOLLAND *"First in Grassland Farming"*



A typical example of long life provided by Ni-Resist. Still practically good as new, this impeller has served for 3½ seasons in the Hale crop sprayer, illustrated, owned by a "custom sprayer", Ben Landis, of Paradise, Pa. The impeller is a product of Olney Foundry, Link-Belt Co., Philadelphia, Pa., producer of Ni-Resist castings.



NI-Resist Impeller in Hale Pump shows

Neither Corrosion nor Wear

after spraying 5,000,000 gallons of insecticides

MONEY-SAVING PERFORMANCE is typical of NI-RESIST®...

Particularly the strong resistance Ni-Resist offers not only to corrosive spraying solutions but also to erosion by solid particles in slurries speeding through equipment at high pressure.

Look at the Ni-Resist impeller shown above, for example. It delivered millions of gallons of highly corrosive insecticides at 400 to 600 pounds pressure. Yet it shows no appreciable deterioration from either wear or corrosion after 3½ seasons of use.

In one season alone, the owner reports, this impeller pumped thousands of gallons of Dithane D-14. Some of the other sprays used were DDT, copper sulphate, zinc sulphate, benzene hydrochloride, lime, sulphur and liquid nitrogen solutions. Since June, 1951, he estimates that it handled a total considerably in excess of 5,000,000 gallons.

After such long and severe use, the good condition of the impeller attests to the high properties which make Ni-Resist castings ideal for holding down costs.

Neither conventional bronzes nor gray cast iron provide a like combination of resistance to corrosion, erosion and wear. Moreover, Ni-Resist castings are not subject to chipping and breaking as are the costly porcelain-coated steel stampings sometimes used in insecticide pumping equipment.

For some years, Hale Fire Pump Company of Conshohocken, Pa., producer of the equipment illustrated above, has standardized on Ni-Resist for pump impellers in their line of crop and orchard sprayers. And Ni-Resist has proved its dependability, beyond doubt.

In fact, no other cast metal provides such a unique combination of useful engineering properties.

Universal adoption of Ni-Resist for spray pump bodies and impellers is warranted by its demonstrated ability to meet the needs of manufacturers and users, alike.

SEVERAL TYPES OF NI-RESIST are available to meet a variety of demands in agriculture and industry. Get full information . . . mail the coupon now.

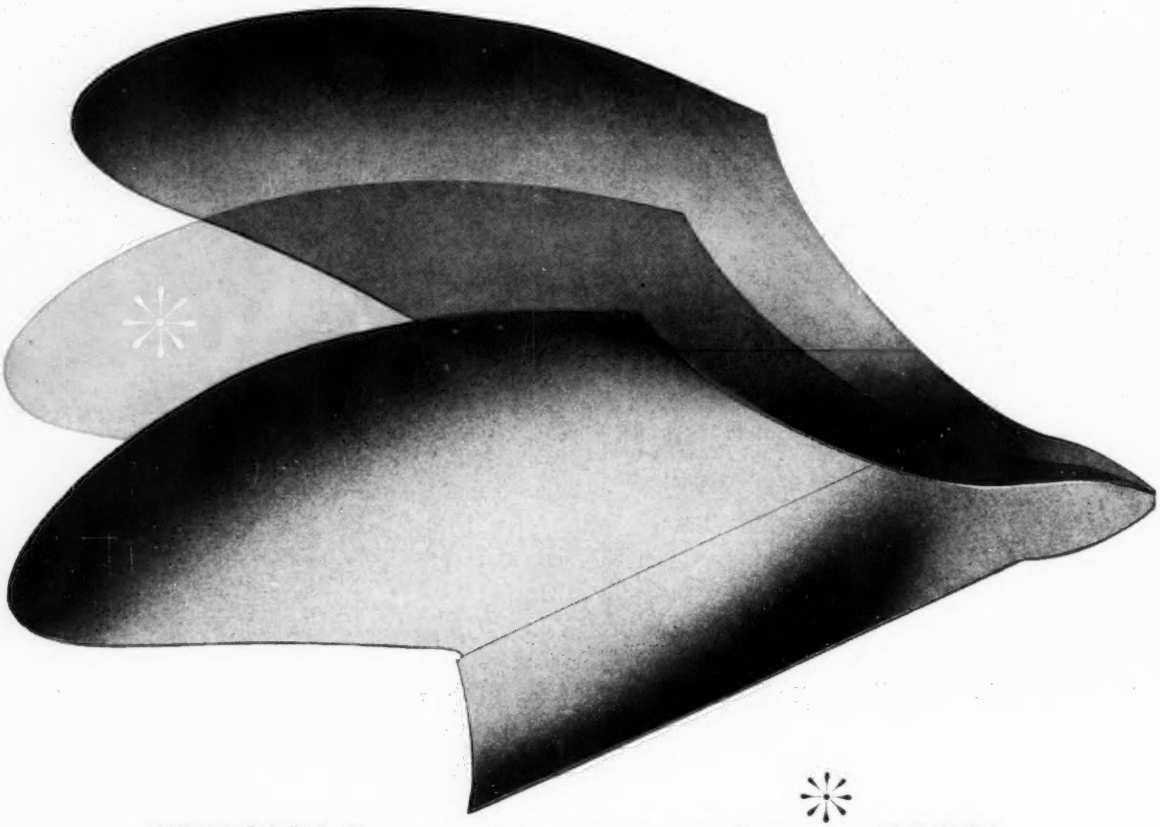
INCO TRADE MARK

The International Nickel Company, Inc.
67 Wall Street, New York 5, N. Y.

Please send me booklets entitled "Engineering Properties and Applications of Ni-Resist" and "Buyers' Guide for Ni-Resist Castings."

Name_____
Title_____
Company_____
Address_____
City_____ State_____

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.



CRUCIBLE **soft center** STEEL

means longer life for moldboards and shares

Plow bottoms made of Crucible *soft center* steel take the bumps and blows of plowing in their stride . . . for between the two outer working layers of tough, hard carbon steel is a soft layer that absorbs the punishment.

Here again, the development of *soft center* steel was a result of Crucible's special *steelmaking* experience. For it takes *steelmen* to produce a steel that will give just the proper amount of surface hardness and center softness to resist chipping or breakage, smooth finish for better scouring . . . and long service.

Yes, when it comes to steel, you can count on Crucible. And for satisfied customers, be sure you sell 'em Crucible *soft center* tillage steels, LaBelle discs and colter blades.

CRUCIBLE first name in special purpose steels

54 years of Fine steelmaking **AGRICULTURAL STEELS**

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

REZISTAL STAINLESS • REX HIGH SPEED • TOOL • ALLOY • MAX-EL • SPECIAL PURPOSE STEELS

How does this affect ag engineers?

Lifting milk cans will soon be a disappearing job. Better methods are taking over. Handling milk in bulk tanks and pipe-line milkers saves time and effort . . . and it assures premium quality, sanitary milk with less waste.

The design of this stainless equipment is a new challenge to ag engineers. And so is the development of better accessory equipment. If this new stainless equipment can do so much for the farmer, isn't there also a challenge to develop even better bulk tanks, milking machines, washing facilities and milk room equipment?

Agricultural engineers working on these developments deal with a material that is relatively new for farm use. Stainless steel has its own characteristics and qualities that must be known in design work.

Armco's long experience in manufacturing and fabricating stainless steel is available to ag engineers in any field.

Send us the coupon below for further information on Armco Stainless Steels and bulk milk handling equipment.

ARMCO STEEL CORPORATION
454-A Curtis Street, Middletown, Ohio

Please send me:

- ☐ Information on Armco Stainless Steels.
- ☐ List of bulk milk tank manufacturers.
- ☐ List of pipe-line milker manufacturers.

Name _____

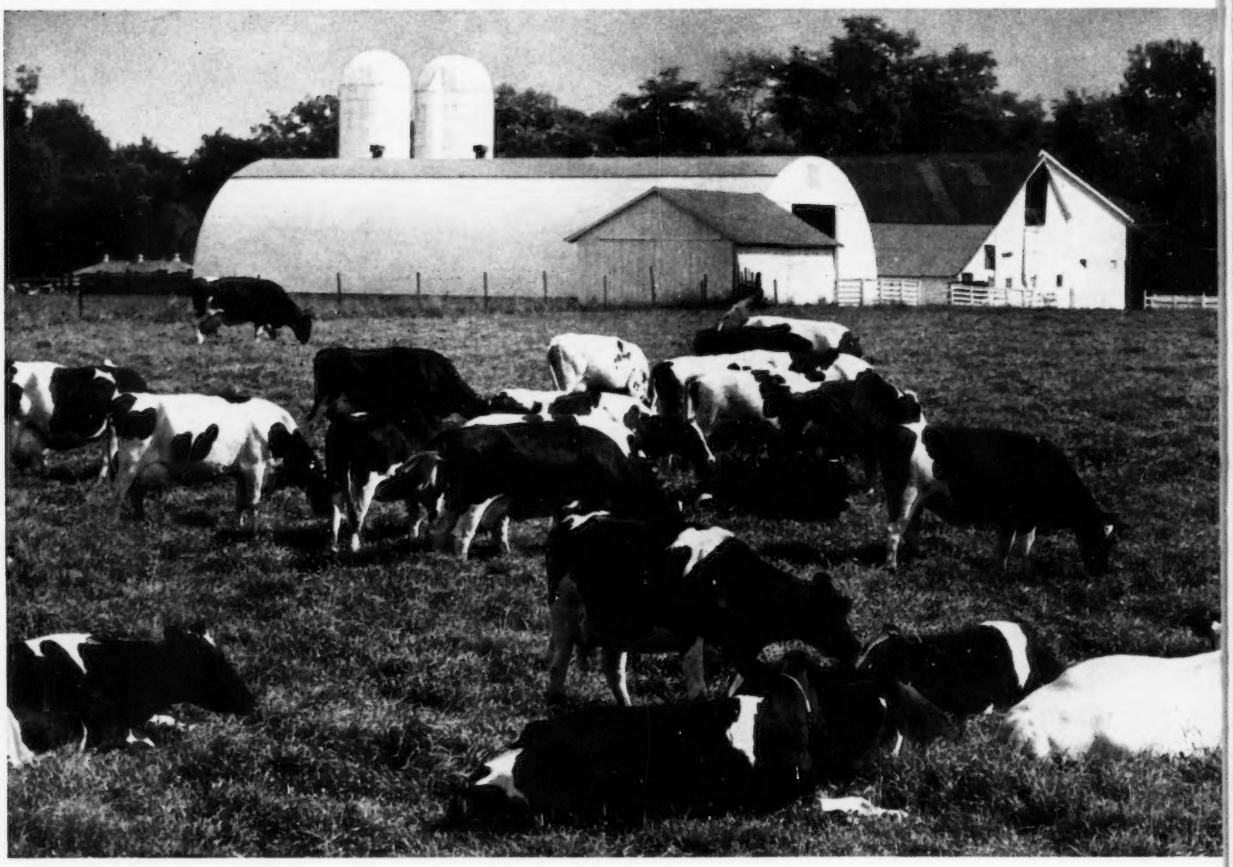
Address _____

City _____ *State* _____

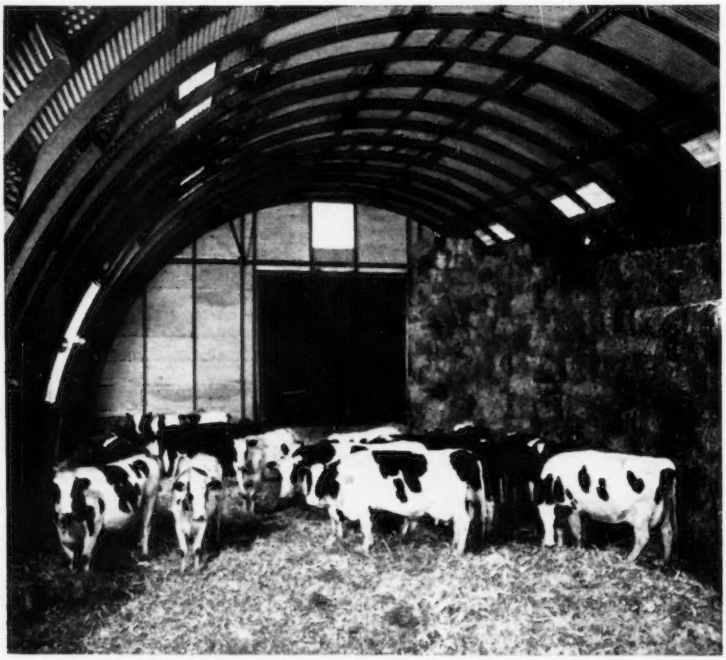
ARMCO STEEL CORPORATION
MIDDLETOWN, OHIO

ARMCO®

SHEFFIELD STEEL • ARMCO DRAINAGE & METAL PRODUCTS, INC. • THE ARMCO INTERNATIONAL CORPORATION

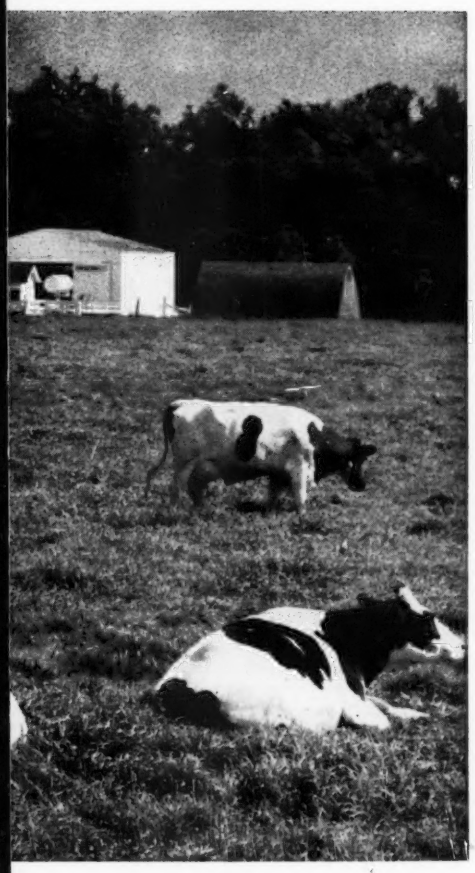


Walt Fisher's top cow is a 604-pounder. Five heifers in his herd passed the 500-pound mark this year. To make the team they have to hit 450 pounds or more in the first two lactation periods or out they go. To get production on this level Walt uses lines of his own choosing in an artificial breeding program, bolstered by use of his own bull when he can't get the lines



This Quonset 40 by 100 loose housing barn is the key to Fisher's labor problems. He stores a year's bedding and some hay on one side of the barn, feeds the hay in bunks just outside the barn and cleans out the manure pack once a year. "I haven't had a single case of mastitis since I went to loose housing," Fisher says. "And before I was the vet's best customer." And he finds it easy to get the manure pack out of the post-free Quonset interior with little labor.

This Quonset 16, equipped with a drying fan and tunnel, lets Fisher store and dry his soybeans, wheat, oats or corn without worrying about loss of any of the grain from moisture. He's looking at some of the 1,500 bushels of wheat harvested this year, now under seal at support price. He parks tractors in the building when it's empty



Management means more milk

Good management boosted the DHIA average of this 35-cow herd 113 pounds in one year. Here's how the owner went about it.

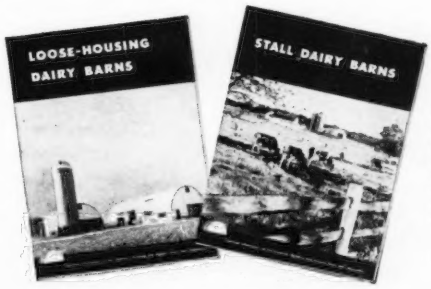
Walt Fisher's milking 35 registered Holsteins on his 340-acre farm at Muncie, Ind., plans to go to 50 soon. Last year his DHIA average was 374 pounds, this year 487 pounds. Here's why.

He's owned the farm for seven years, decided three years ago it could make money. He built up his land to produce more feed, built up his herd to produce more milk and then he added to his buildings to cut his labor requirements.

He's got a 7-year rotation, feeds 213 tons of grass silage, 75-80 tons of hay a year. He raises 60 acres of corn a year, some soybeans, and some oats or wheat. He covers 30 acres a year with manure, fertilizes his pasture seedings with 500 pounds of 3-12-12 fertilizer. He switched to a loose-housing system last year to cut his labor, uses his old barn for hay storage and a milking parlor. He's shooting for a 500-pound herd average and it looks like he'll make it.

he wants. He uses 8 lbs. alfalfa, 4 lbs. brome, 2 lbs. timothy and half a pound of ladino in his pasture seedings. He considers manure second in importance to milk as a crop, side dresses his oats or wheat with liberal nitrogen to produce more straw for his manure pack. This year Walt got 40-bushel wheat from his 35-acre planting, and his 60 acres of corn went about 80 bushels.

Fisher figures his Quonset 24 machinery storage building and shop is one of the "workingest" buildings he has. He cuts depreciation loss on his machinery, gets all of it ready to go during the winter and saves valuable time during his busy seasons because he has fewer breakdowns.



Two new handbooks on modern DAIRY BARNS

Authentic, authoritative and amply illustrated, these two handbooks summarize latest practical information on stall-type barns and loose-housing systems—help you plan for efficient production. For copy of one, or both—

Write to STRAN-STEEL DIVISION

There's a Quonset® for Every Job on your Farmstead

YOU NAIL TO STRAN STEEL FRAMING

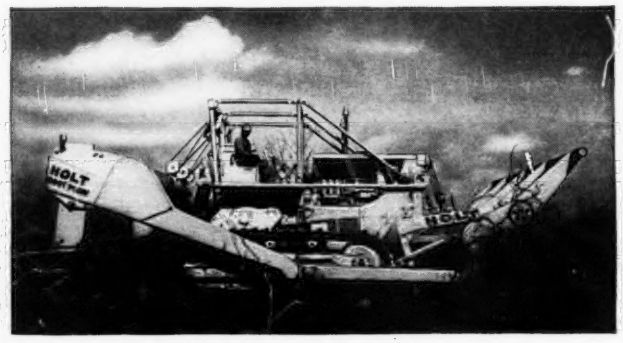
GREAT LAKES STEEL CORPORATION

Stran-Steel Division Ecorse, Detroit 29, Mich.

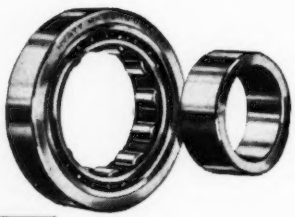
NATIONAL STEEL CORPORATION

PRODUCER OF NAX HIGH-TENSILE STEEL

THE BIGGER THEY COME...



the greater the need for HYATT BEARINGS!



Not an atomic tank, but a "king-sized Cat"—used to clear mesquite from Texas ranches. Built by the Peterson Tractor & Equipment Company, of San Leandro, California, the giant tractor pictured above is actually two Caterpillar D-8's joined together—each with the inner track and driving mechanism removed. And in the new final drives—necessary because of increased ground clearance—the builders naturally used Hyatt Roller Bearings, the same precision bearings as those used throughout the standard tractors. As always, Hyatts were specified because they can be counted on to hold maintenance costs to a minimum while reducing friction and wear.

HYATT

ROLLER BEARINGS

STRAIGHT ◯ BARREL ◯ TAPER ◯

HYATT BEARINGS DIVISION • GENERAL MOTORS CORPORATION • HARRISON, NEW JERSEY

AGRICULTURAL ENGINEERING

VOL. 35 OCTOBER, 1954 NO. 10

Heat Required to Vaporize Moisture

. . . In Wheat and Shelled Corn During the Process of Artificial Drying

H. K. Johnson and A. C. Dale
Assoc. Member ASAE Member ASAE

EVALUATION of systems and design of equipment for processing operations such as artificial drying of grain usually require information on three aspects of the basic process: *(a)* the amount of energy required, *(b)* the rate at which the process may be made to proceed, and *(c)* the extent to which the process may be carried, or the equilibrium point.

This study is concerned primarily with the first aspect of the basic process, the determination of the energy required to vaporize grain moisture during a drying process. The experimental method required the determination of drying rates for calculation of heat requirement, but the magnitude of the drying rate was not studied with regard to grain properties and air conditions. There are several sources of information on the equilibrium relationship between the relative humidity and temperature of the air, and the grain moisture. These are of value only as they facilitate semi-theoretical methods for predicting heat requirements from vapor pressure data by thermodynamic considerations.

Experience with grain-drying processes has indicated that the energy required to evaporate a quantity of moisture from grain is near that required to evaporate the same amount of free water over the range of moisture contents encountered in commercial drying operations. Since grain is a hygroscopic material, i.e., it exhibits a vapor pressure less than that of free water at the same temperature, it would be expected that the heat requirement would be somewhat above that for free water and that there would be an increase in this quantity as drying is carried to lower moisture levels. This supposition is verified by limited data on grain-drying processes and from study of other hygroscopic materials.

There is little information available on the manner in which the energy requirement is dependent on the type of grain, moisture content, drying temperature, and drying rate. This paper describes a method of measuring the heat of vaporization and the results obtained in drying tests on wheat and shelled corn.

Heat of Vaporization Predicted from Vapor Pressure Data

Hygroscopic materials such as grain contain moisture which is held within the material by physical and chemical forces. The exact mechanism which is effective in the attachment of water in the colloidal material of the grain kernel is not fully understood. According to Henderson (7)* the predominant fixing mechanism is adsorption, although solution, hydration, chemical combination, and capillarity are factors which may be present.

"Adsorption" refers to the phenomena associated with the retention and concentration of molecules on solid surfaces; it occurs on the surface of a solid substance because of the existence of certain surface forces. When a gas or vapor is exposed to the solid, the gas molecules become distributed between the gas phase and the adsorbed phase; the concentration of the gas in the adsorbed phase proceeds until a condition of equilibrium is reached. The amount of gas or vapor adsorbed depends on the nature of the gas and the solid, temperature, and pressure of the gas or vapor.

Biochemical changes occur so slowly in grain containing up to 14 percent moisture that it is difficult to detect respiration of the living cells. According to Kretovich (8), the explanation of this fact lies in the theory of bound water, i.e., water which is so bound to the grain colloids, particularly proteinaceous substances, that it cannot serve as a solvent and medium in which biochemical changes can occur in the living cell. Also, it has been noted that such water does not freeze at temperatures below the freezing point of free water. Kretovich presents data on the proportion of free and bound water for various moisture contents of wheat; at a moisture content of 15.6 percent, over 90 percent of the total water in the grain is reported as bound water and at a moisture content of 30 percent free and bound water are present in about equal quantities. (The moisture contents are in percent wet basis.)

Grain-drying processes, which usually lower the moisture content to 12 to 14 percent, apparently involve the removal of both free and bound or adsorbed water.

The heat required for a phase change may be predicted from thermodynamic considerations. Othmer (11) devised a method using vapor pressures at different temperatures and based upon the Clapeyron equation. This equation is developed and applied in thermodynamics texts, e.g., Glasstone (5); it may be expressed in the form

$$dP/dT = L/(V-v)T$$

where P = vapor pressure

T = absolute temperature

V = specific volume of saturated vapor

v = specific volume of saturated liquid

L = heat of vaporization at average temperature, T.

This paper was prepared expressly for AGRICULTURAL ENGINEERING. It is based on research work performed under Project 273, "Determination of Drying Rate of Grains in Bulk Air Drying Systems," in the department of agricultural engineering, Purdue University Agricultural Experiment Station, and is approved as Journal Paper No. 798.

The authors—H. K. JOHNSON and A. C. DALE—are, respectively, formerly junior assistant in agricultural engineering, Purdue University, and now research engineer, Cargill, Inc., and associate in agricultural engineering, Purdue University Agricultural Experiment Station.

*Numbers in parentheses refer to the appended bibliography.

If the vapor is assumed to behave as an ideal gas and the volume of the liquid is neglected, the equation becomes

$$dP/dT = LP/RT^2$$

where R = gas constant.

This form is known as the Clausius-Clapeyron equation. The method of Othmer makes use of the preceding equation to predict the heat of vaporization of one liquid if the heat of vaporization of another liquid is known at the same temperature and there is available vapor-pressure data for the two liquids. The equation developed is

$$\log P = L/L' \log P' + C$$

where P = vapor pressure of one liquid
P' = vapor pressure of second liquid
L = heat of vaporization of first liquid
L' = heat of vaporization of second liquid
C = constant of integration.

It is evident from the above equations that if the vapor pressures are plotted on a log-log chart, the slope of the resulting line will be equal to the ratio of the heats of vaporization. This method was used by Gallaher (3) to predict the heat of vaporization of moisture in wheat. In the case of grain moisture the most convenient reference liquid is free water since abundant data for this substance are available in the form of steam tables.

The preceding method of predicting heat of vaporization is based on *equilibrium* vapor-pressure data. The equilibrium condition does not prevail during a drying process; in fact it is the non-equilibrium condition, with respect to vapor pressures of moisture in grain and that in the drying air, which provides the potential or driving force for the drying process. Some indications of the nature of moisture gradients which may be existent within the kernels during drying is given by MacMasters (9) in the statement that most of the corn kernel is covered with a thick layer of relatively waterproof material, and that the open type of tissue at the tip of the grain kernel is probably the exit space for moisture during the drying process.

The non-equilibrium condition which prevails during a drying process is a limitation in application of the Clausius-Clapeyron equation. During a drying process, the grain kernels may have a certain mean moisture content measured by weighing, but this is not necessarily the moisture content at the regions where vaporization is actually occurring. The grain kernel is composed of a somewhat dense material which offers resistance to the movement of moisture from the interior to the surface in contact with the ambient air. Moreover, the particle is non-uniform in shape and also heterogeneous in physical and chemical properties.

Even with these limitations, it is of interest to investigate the predicted values of the heat of vaporization of water in grain of various moisture contents based on equilibrium vapor-pressure data. According to the equations derived from thermodynamic considerations, the heat of vaporization of a liquid, (for example, the heat of vaporization of water in grain at a given moisture content), may be calculated if the vapor pressure, temperature, and rate of change of vapor pressure with temperature can be measured. Several studies of the equilibrium conditions between various types of grain and ambient air have been conducted. However, since the rate of change of vapor pressure with temperature must be known, only those studies which include temperature as a pertinent variable are useful in supplying data for application of the Clausius-Clapeyron equation for calculating heat of vaporization. Several workers have mentioned a shift in equilibrium with change in temperature, but only meager quantitative data are available.

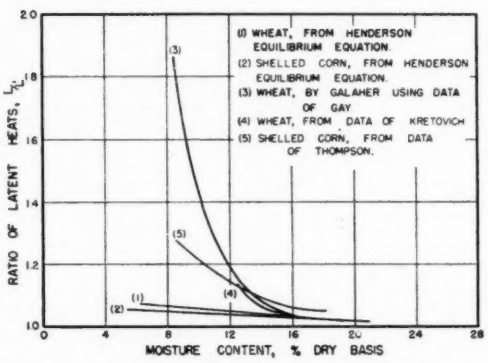


Fig. 1 Variation in heat of vaporization with moisture content, calculated from vapor-pressure data

Fig. 1 shows the variation in heat requirement with moisture content as calculated by the method of Othmer and using vapor-pressure data from various sources as indicated on the graph. It is apparent that rather accurate data on the moisture-relative humidity-temperature relation for hygroscopic materials, such as wheat or shelled corn, must be available if the heat required for vaporization is to be calculated by methods based on the Clausius-Clapeyron equation. However, the results of calculations based on vapor-pressure data from various sources indicate that the heat requirement would increase during a drying process on wheat or shelled corn, particularly if the moisture content is reduced to less than 12 to 14 percent dry basis.

Only limited experimental work has been done on the direct determination of the heat of vaporization for hygroscopic materials in general. The work of Argue and Maass (1) on cellulose and wood pulp shows an increase in heat requirement with decreasing moisture content. These data were obtained by measuring the heat of wetting (heat of adsorption) rather than heat of vaporization or heat of desorption. Newsome and Sheppard (10) reported similar work on cellulose acetate. Babbitt (2) calculated heats of adsorption by the Clapeyron equation in his analysis of the absorption of water by cellulose.

Gregory (6) developed an experimental method for measuring directly the heat of vaporization of moisture in wheat during a drying process. The results of tests made at two drying temperatures showed heat requirements which were somewhat greater than those predicted by Gallaher (3) using the Clapeyron equation and vapor-pressure data.

Experimental Method

In view of the difficulties encountered in calculating the amount of heat required to vaporize grain moisture and of the uncertainty involved in applying the results to actual drying processes for wheat and shelled corn, a method was developed for measuring directly the heat requirement during a drying process. This experimental procedure made possible the measurement of heat required at various moisture contents during drying processes at different temperatures and beginning from different initial grain moisture contents.

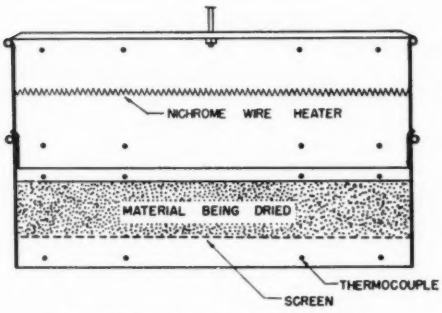


Fig. 2 Drying pan and heater assembly

The method employed was based on the measurement of the sensible heat loss of an air stream flowing through a thin layer of grain; it was developed by modification and refinement of the procedure used by Gregory (6) in measurement of heat required for vaporizing moisture in wheat. Drying of the grain layer was effected under such conditions that essentially all heat lost by the air in passage through the grain layer was used to vaporize grain moisture. Measurement of the rate of moisture removal during the process provided the additional information required to calculate the heat supplied per unit of water evaporated.

The grain being dried was contained in a pan with a screen-mesh bottom. The construction of the grain container with attached flow-measuring apparatus is illustrated in Fig. 2. Immediately above the grain pan was an electrical heater made of nichrome wire and placed to uniformly cover the area of the air flow path. A thermopile, exactly like the thermopile used at the grain layer, was placed with alternate thermocouples above and below the heating element, thus providing a means of measuring temperature increase in the air stream. Fig. 3 is a schematic diagram of the thermopiles used to measure temperature change of the air in passing through the grain and heater sections.

Similar heat exchange equations may be written for the grain layer and heater section:

$$Q_G = C\,W\,\Delta T_G \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [1]$$

$$Q_H = C\,W\,\Delta T_H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [2]$$

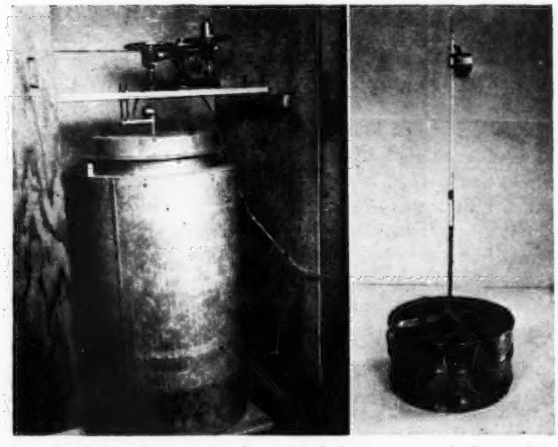


Fig. 4 *(Left)* Drying chamber with balance mounted above. The micromanometer was used to regulate air pressure in the plenum chamber below • Fig. 5 *(Right)* Drying pan and heater assembly with suspension rod and electrical contacts

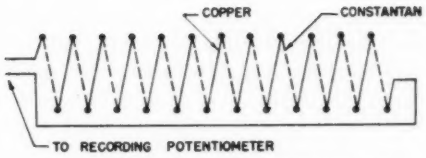


Fig. 3 Schematic drawing of thermopile

where W = weight rate of air flow
C = thermal capacity
Q_G = heat loss of air in grain layer
Q_H = heat gain of air in heater section
ΔT_G = temperature drop of air through grain layer
ΔT_H = temperature rise of air through heater section.

Since the energy input to the heater could be measured by an ammeter and voltmeter, equations [1] and [2] are conveniently combined:

$$Q_G = (\Delta T_G / \Delta T_H)\, Q_H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [3]$$

Equation [3] demands that exactly the same flow rate be maintained through the grain layer and heater section; construction of the grain pan-heater assembly was such that this was ensured.

According to equation [3], the heat supplied to the layer of grain may be determined by measurement of two temperature differences and the energy supplied to the flow measurement heater. Since the magnitude of both ΔT_G and ΔT_H was relatively small, less than 2 F, a linear relation may be assumed between temperature difference and voltage generated by the thermocouples. Thus it was necessary to measure only the ratio between two thermal voltages.

To find heat supplied per unit of water evaporated at any time and moisture content during the drying process, the rate of drying must be known at the time under consideration. The weight of the grain was recorded at intervals during a test; this provided data for a drying curve of weight vs. time. The rate of drying, dM/dt, where M is weight of grain and t is time, was found by a numerical method. This factor may be incorporated in equation [3] to yield an expression for the desired quantity, heat per unit of water evaporated.

$$L = \frac{\Delta T_G\, Q_H}{\Delta T_H\, dM/dt}$$

where L = heat required per unit of water vaporized.

The drying chamber, shown in Fig. 4, was constructed of 22-gage sheet metal. The central duct in which the drying pan assembly was suspended, was 9 in in diameter and insulated by 3 in of vermiculite insulation. Surrounding this duct was a shell, annular in cross section, through which flowed a part of the total air flow supplied to the entire drying chamber. The shell was enclosed by another double wall of 1½ in thickness containing vermiculite insulation.

Air for the drying process was heated to the desired temperature by electrical strip heaters upstream of the drying chamber. In order to obtain constant air temperature at the drying chamber, it was necessary to maintain a constant flow rate over these heaters, since it was not feasible to install temperature-regulating equipment sensitive enough to maintain the desired constant temperature with the variable-flow rates. The central duct and the shell were provided with variable openings at the air outlets. When it was desired to

change the air flow rate through the central duct, these openings were so adjusted that a constant static pressure under the drying chamber was maintained. Thus only the fractions of the total flow going to the two flow channels was changed; the total flow was constant and, there was no temperature change in air delivered by the upstream heaters.

Because it was necessary to periodically weigh the complete grain pan assembly, a damper was provided in the central duct for stopping the air flow momentarily, while the scale was balanced.

To ensure that air would be forced through the grain in the pan and that the flow rate through the pan would be the same after each weighing, a mercury seal was used at the bottom edge of the drying pan. The seal consisted of a ring of mercury, contained in a plywood groove, into which the bottom edge of the drying pan was immersed except during weighing when the pan was suspended from the balance.

Similar thermopiles were used for the grain layer and the flow measuring heater. These thermopiles, shown schematically in Fig. 3, consisted of twelve pairs of copper-constantan thermocouples placed to uniformly cover the area of the flow path. The use of twelve pairs of sensing elements resulted in an average reading for the cross section where they were located, and, since the voltages of thermocouples in series are additive, the sensing elements provided thermal voltages of sufficient magnitude to be accurately measured and recorded by the potentiometer available.

The drying pan and heater section assembly is shown in Fig. 5.

A 16-point Brown Electronik recording potentiometer was used to record the thermal voltages. This instrument originally had a range of about 3 mv; however, since the temperature differences to be measured by the thermopiles were less than 2 F, the resistances in the internal circuit of the instrument were changed to produce a full scale deflection of the recorder with an imposed voltage of about 0.8 mv. It was found that the instrument, altered in this manner, provided a satisfactory degree of accuracy in measuring the thermal voltages for even the small temperature differences (less than 0.3 F) which prevailed near the end of a drying test when the drying rate was low.

Alternate terminals of the recorder were short-circuited to print a record of the base point or zero voltage. Switching in the instrument was automatic and at 15-sec intervals. Thus the voltage from each of the two thermopiles was measured once each minute. For this instrument, displacement of the printer was directly proportional to the imposed voltage; voltage was assumed to be directly proportional to temperature difference without significant error. Hence it was unnecessary to calibrate the instrument displacement in terms of voltage or temperature, since only a ratio of temperatures was required; the ratio of displacements was assumed to be equal to the ratio of temperature differences.

The temperature-sensitive resistance originally provided in the potentiometer circuit for cold-junction compensation was replaced by a fixed resistance, since the instrument was used to measure small voltages rather than temperature. The linearity between potentiometer displacement and imposed voltage was checked by feeding voltages to the recorder from a Leeds and Northrup portable precision potentiometer.

All of the thermocouples were located in the drying-pan assembly; it was necessary to break the electrical circuits during weighing in order to balance the scale quickly and accurately without interference from the thermopile lead wires or the conductors to the flow-rate heater. A set of mercury contacts was provided; when the drying pan assembly was raised in balancing the scale, the points were lifted from the mercury, thus breaking the circuits during weighing.

TABLE 1. SUMMARY OF DRYING CONDITIONS

Test No.	Grain	Initial moisture, % Wet bulb	Initial moisture, % Dry bulb	Drying Temp., deg F
1	Wheat	26.0	35.1	110
2	Wheat	26.0	35.1	130
3	Wheat	18.0	21.9	130
4	Wheat	18.0	21.9	150
5	Shelled corn	18.0	21.9	110
6	Shelled corn	18.0	21.9	130
7	Shelled corn	22.0	28.2	130
8	Shelled corn	26.0	35.1	130
9	Shelled corn	18.0	21.9	150
10	Shelled corn	26.0	35.1	150

A single thermocouple was placed at the bottom of the drying pan near the level of air entrance into the grain layer. This thermocouple was connected to a Brown indicating potentiometer. The calibration of this instrument was checked at the ice point and boiling point of water.

Energy to the flow-measurement heater was controlled manually by a voltage regulator. Although alternating current was used for this heater, the wattage could be determined by an ammeter and voltmeter since the heater was found to be non-inductive by oscilloscope test.

Tests on Shelled Corn and Wheat

Small lots of grain to be dried were prepared by adding water to good quality shelled corn and wheat. Samples of shelled corn were prepared to give three moisture levels, 18, 22 and 26 percent wet basis. Water was added to wheat so that two moisture levels, 18 and 26 percent, were available for drying tests. No tests were made for at least one week after the grain was wetted to ensure moisture equilibrium throughout the kernels. The high-moisture grain was kept in cold storage at 40 F; several hours were allowed for the grain to reach room temperature before being placed in the drying chamber.

In order to evaluate the effect of drying-air temperature on heat required to vaporize grain moisture, three temperatures were used in the series of drying tests, 110, 130 and 150 F. The use of temperatures in this range provided drying-air relative humidities low enough to allow drying to moisture contents considerably below the lower moisture limits common in commercial drying operations. The experimental method required that the drying rates be great enough to be measured with a satisfactory degree of accuracy even at the lower moisture contents when the drying potential was low. Drying temperatures of 110 to 150 F allowed the measurement of temperature drops and drying rates with reasonable accuracy at moisture contents as low as 9 to 10 percent dry basis.

The volume of air supplied to the grain layer was relatively large; in fact, the air-flow rate was always sufficient to ensure that the rate of drying was limited by rate of moisture movement from the interior to the surface of grain kernels rather than by the quantity of air supplied. If the air-flow rate through a layer of grain is so great that the temperature

drop of the air is very small in passage through the layer, the whole layer dries at almost the maximum rate which is dependent on properties of grain and air: air temperature and humidity, grain temperature, grain moisture content, and mass transfer resistance within the material of the grain kernels. Under these conditions air-flow rate is not a pertinent variable with regard to drying rate. This type of drying process was termed "thin layer" drying by Page (12) in studies of maximum drying rates of shelled corn. The small temperature drop across the grain layer allows the assumption of negligible moisture gradient from bottom to top of the layer; moisture content of the grain at any time was calculated from weight of the grain.

The air-flow rate was changed at least once during each drying test in order to maintain temperature drops across the grain layer in the range of 0.3 to 2.0 F. Wattage supplied to the flow-rate heater was regulated to provide about the same range of temperature change across the heater section. No temperature data from the first 20 min of any test was used in calculating heat requirements. During this period sensible heat exchange between grain and air could not be neglected; some of the heat lost by the airstream was being used to raise the grain temperature to the drying temperature. Except for this initial warmup period, it was assumed that all sensible heat lost by the air was used to vaporize grain moisture.

At the completion of a drying test the sample of grain was removed from the drying chamber and placed in an air oven for 24 hr at 105 C. The weight of the sample at this time was assumed to be the weight of dry matter and all calculations of moisture content were based on this method of moisture testing.

Results

A series of drying tests was designed to provide data on heat required to vaporize grain moisture at various moisture contents during a drying process. Three drying temperatures and three initial moisture contents were used in tests on shelled corn; three drying temperatures and two initial moisture contents were used in tests on wheat. A summary of the tests is shown in Table 1.

The moisture content during drying was found to have the greatest effect on heat requirement. The other factors, drying temperature and initial moisture, were of minor significance over the range of temperatures and moisture levels covered in these tests.

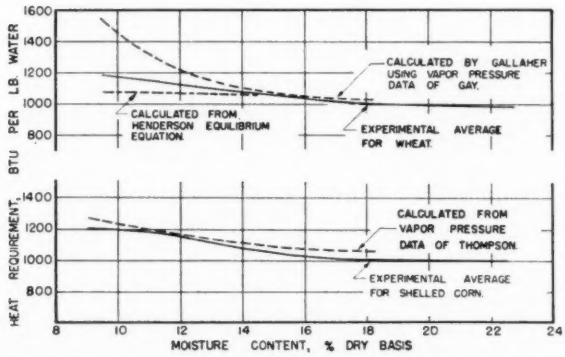


Fig. 6 Average experimental heat requirement for wheat and shelled corn compared with values predicted from vapor-pressure data

The drying tests on wheat and shelled corn indicated a moderate increase in heat required to vaporize grain moisture as the drying process was carried to lower moisture levels.

Data were obtained for a total moisture range of about 8 to 22 percent dry basis, but it was not possible to measure heat requirement for this range of moistures in any one test. Use of high temperature (150 F) caused the drying rates during the first part of a test to be so great that the moisture content was considerably below the initial moisture before any data could be obtained which was satisfactory for use in calculating heat requirement. The use of the lower drying temperature (110 F) facilitated measurements at the relatively high moisture contents but drying rates soon became so low that they could not be measured with the desired accuracy. Different initial moistures and temperatures resulted in different ranges of moisture content covered in the various tests.

Drying temperature and initial moisture had no marked effect on the measured heat requirement at any given moisture content, even when drying rates and potentials causing moisture gradient within the kernels were greatly different. For example, at the 12 percent moisture level, shelled corn required 1080 Btu per lb of water in test No. 5 at a drying temperature of 110 F and the drying rate was 0.05 g per min. Test No. 9 (150 F) resulted in a drying rate of 0.199 g per min at a moisture of 12 percent and the heat requirement was 1120 Btu per lb of water. Even though one drying rate was almost four times the other, the difference in heat requirement is not considered significant.

These results indicate that the average kernel moisture content as computed from the weight of the sample provides a fairly accurate measure of the moisture content at the region of vaporization. Therefore it is reasonable to assume that the kernel during drying consists of a relatively moisture impervious layer surrounding water-permeable material with a fairly uniform moisture content. Thus the moisture gradient, though necessarily present during drying, would have but little influence on the heat required for moisture vaporization at a given average kernel moisture content.

Since heat requirement was found to be essentially dependent only upon moisture content, the results of the various tests were averaged and a curve of average heat requirement versus moisture content was plotted for each of the grains, wheat and shelled corn, in Fig. 6. These average curves represent all of the data within 5 percent. A comparison of the average experimental heat requirement with the values calculated from vapor-pressure data is also shown in Fig. 6.

The average curves for both wheat and shelled corn show a heat requirement of 1080 Btu per lb of water at a moisture content of 14 percent dry basis, which is about the lower limit of moisture for most actual drying installations. This is approximately 6 percent above the heat of vaporization of free water in the temperature range of these tests. Thus it appears that the greater part of the water removed from grain in most full-scale drying processes is evaporated at moisture levels such that the hygroscopic or moisture-binding effect results in no marked increase in energy required for moisture vaporization. Some drying systems utilize air-flow rates and temperatures which result in considerable overdrying of a part of the grain; therefore, moisture contents

(Continued on page 714)

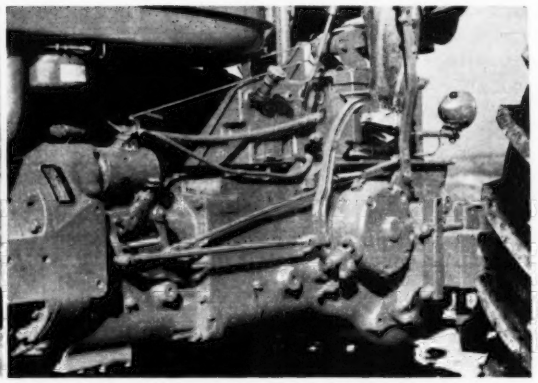


Fig. 1 *(Left)* The Farmall Super M-TA tractor equipped with the new torque-amplifier drive • Fig. 2 *(Right)* Control linkage and levers adjacent to the torque-amplifier handle and clutch pedal

New Farmall Tractor Torque Amplifier

. . . *A Planetary Drive Unit Providing Additional Forward and Reverse Travel Speeds*

Henry A. Ferguson

SINCE March of this year the International Harvester Company has been delivering the new Farmall Super M-TA tractor equipped with a transmission drive providing considerable advancement in tractor operation by its ability to do more work than ever before. This new tractor succeeds the former Farmall Super-M and is, to the best of our knowledge, the first production unit in the industry to embody the "torque amplifier," a compound spur-gear-planetary speed-reduction unit installed between the engine master clutch and the conventional five-speed sliding-gear transmission.

The tractor equipped with the torque-amplifier drive is shown in Fig. 1. This new feature is compacted into the over-all silhouette of the tractor so that all principal tillage, planting, and harvesting tools can be used without change. The torque amplifier provides five (5) additional forward speeds and one (1) additional reverse speed to give a total of ten (10) forward and two (2) reverse speeds for tractor propulsion. The tractor operator can instantly reduce travel speed 33 percent and, at the same time, increase drawbar pull up to 45 percent in any selected gear without stopping, without declutching, without shifting, and without touching the governor control or throttle setting. The power flow to the rear wheels is uninterrupted and the operation of the torque amplifier is quickly and easily controlled by means of a lever at the left side of the driver.

Paper presented at the annual meeting of the American Society of Agricultural Engineers at Minneapolis, Minn., June, 1954, on a program arranged by the Power and Machinery Division.

The author—HENRY A. FERGUSON—is divisional chief engineer, advanced engineering group, farm tractor division, International Harvester Co.

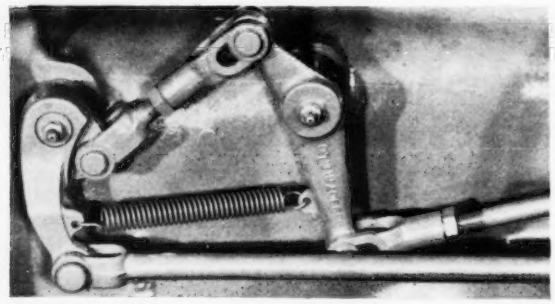


Fig. 3 Close-up of interlinking levers connecting the master engine clutch and torque-amplifier clutch

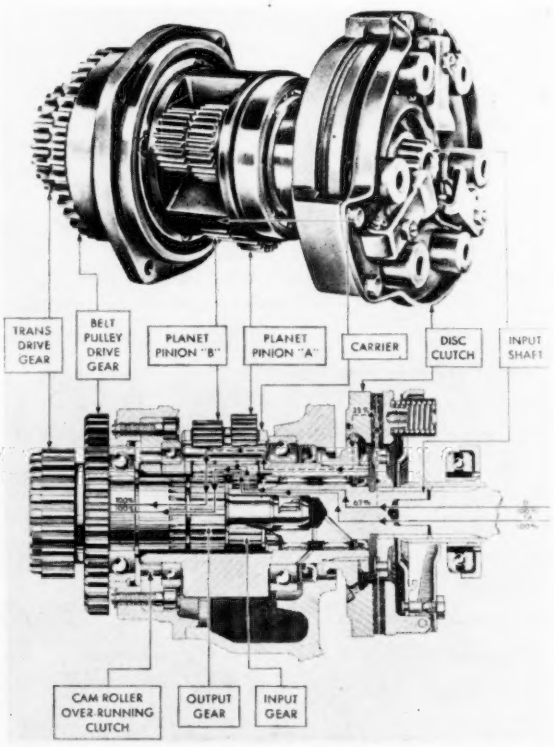


Fig. 4 Sectional side view of the torque-amplifier mechanism

The control linkage and levers adjacent to the torque-amplifier handle and clutch pedal are shown in Fig. 2. This mechanical cross-linkage system actuates the torque-amplifier where it is required to negotiate loads caused by changing soil or field conditions, and provides a simple means for keeping a proper relationship between the torque-amplifier clutch and master engine clutch.

Fig. 3 is a close-up of the interlinking levers connecting the master engine clutch and torque-amplifier clutch so that the latter is also disengaged when the clutch pedal is fully depressed. This feature is necessary for certain field operations in order to allow easy selective shifting of the conventional sliding-gear transmission.

A sectional side view of the torque-amplifier mechanism is shown in Fig. 4. When the torque-amplifier clutch is disengaged to provide the torque-amplified speeds in the transmission proper, power from the engine master clutch is delivered to the input sun gear and transferred through three planet-cluster pinions by tooth contacts at A and B, respectively, thereby delivering power to the output sun gear and into the transmission. Under these conditions the carrier tends to react counter to engine rotation and is constrained from movement by means of the cam and roller one-way or overrunning clutch.

When the torque-amplifier clutch is engaged to provide direct speeds in the transmission proper, power from the master engine clutch is divided at the junction of the input sun-gear shaft and torque-amplifier clutch disk hub so that approximately 33 percent is transmitted through the torque-amplifier clutch into the carrier of the cluster planet pinions. The remaining 67 percent of the input power is passed through the input sun gear to the three planet pinions at A. This power joins that of the carrier at B and total power therefore flows through the output sun gear and into the

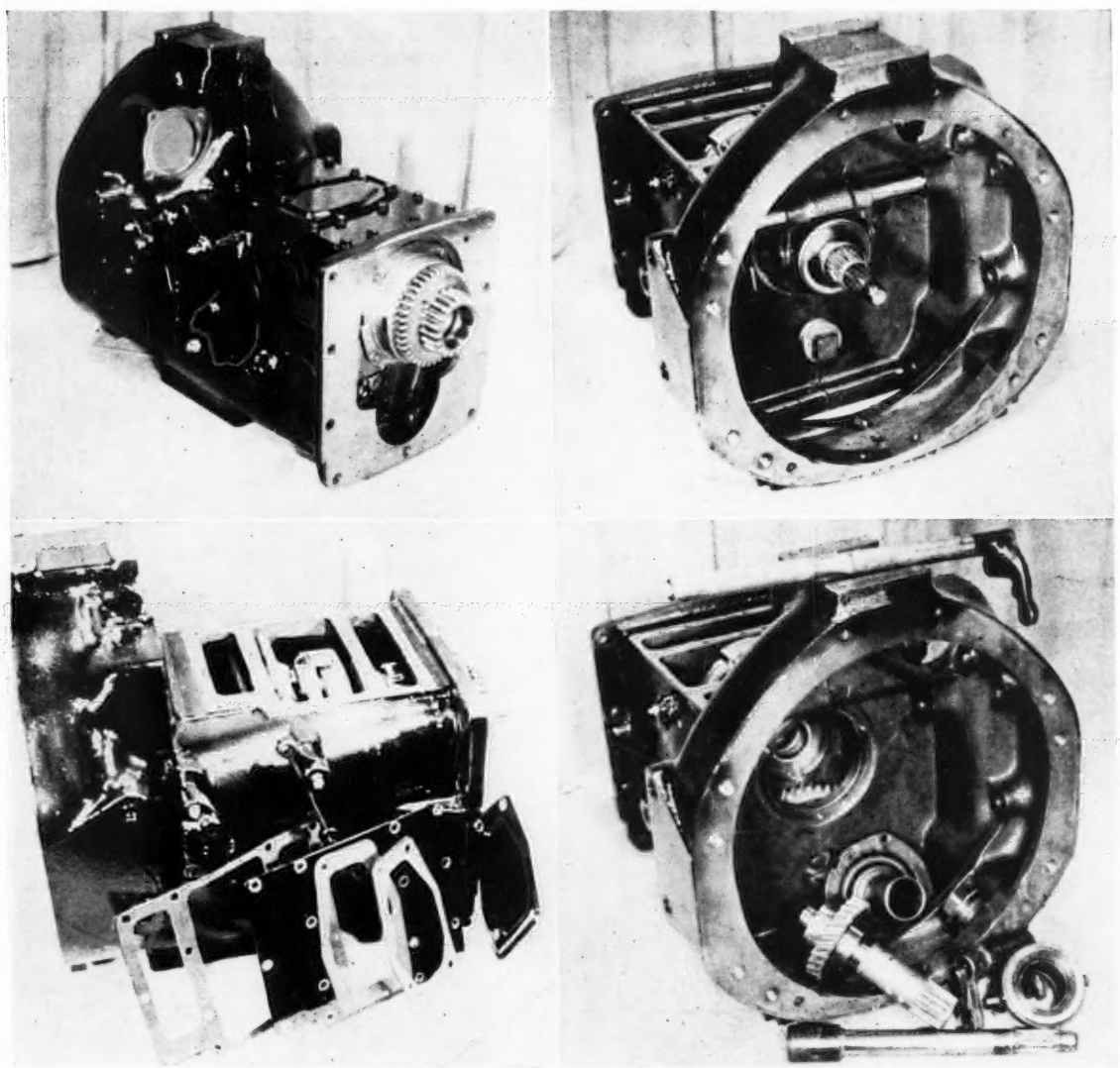


Fig. 6 *(Upper Left)* The complete clutch housing removed from tractor • Fig. 7 *(Upper Right)* A view of the engine master-clutch compartment • Fig. 8 *(Lower Left)* Clutch housing with top cover removed • Fig. 9 *(Lower Right)* Engine clutch-release mechanism disassembled

SPEED	POWER SHIFT	TRANS. RATIO	TOTAL RATIO	M.P.H.	TRACTION LIMITATION
1	N	6.68 T_E	98.8 T_E	2.50	82.1 %
	TA	9.9 T_E	146.4	1.69	55.4 %
2	N	4.34	64.1	3.85	NONE
	TA	6.43	95.0	2.60	84.2 %
3	N	3.46	51.1	4.83	NONE
	TA	5.14	75.8	3.26	NONE
4	N	2.49	36.8	6.71	NONE
	TA	3.69	54.5	4.53	NONE
5	N	1.0	14.8 FINAL DR.	16.70	NONE
	TA	1.482	21.9	11.27	NONE
REV.	N	5.02	74.1	3.33	/
	TA	7.44	109.8	2.25	/

Fig.5 Chart showing effect of the torque amplifier on the transmission and final-drive gear ratios. (Engine governed speed, 1450 rpm; 12x38 tires; 28.6 R.R.)

transmission. In this condition there is no relative motion between the planets and sun gears. The carrier, however, revolves in the same direction and at the same speed as the engine so that the entire torque-amplifier gear train rotates in a locked or one-to-one drive. The cam-roller overrunning clutch freewheels.

The input sun gear is journaled in needle bearings in the carrier and constrained from axial movement by bronze thrust washers. The output sun gear is journaled in a ball bearing and a pilot needle bearing inserted inside of the input sun gear. The carrier member is mounted on ball bearings and supports the torque-amplifier clutch assembly.

Each planet pinion cluster is journaled on hardened rollers running on a hardened steel pinion shaft. End movement of the planet pinions is constrained by means of steel thrust washers. All gears are carburize-hardened to provide sufficient strength in compression and bending.

The overrunning clutch cage includes the cam or ramp surfaces for engaging eight (8) rollers and is flame-hardened to withstand the compressive stresses imposed. Each roller is teased into engagement by a hard bronze pin and spring held for initial assembly by a neoprene plug.

The torque-amplifier gear train is a standard 14 diametral-pitch spur-tooth system. The input sun gear has 23 teeth. Cluster planet pinion portion A has 28 teeth, while its associated portion B has 23 teeth. The output sun gear has 28 teeth. Hence, in torque-amplifier drive the engine torque is multiplied by the ratio 1.482 to 1. However, when in direct drive there is no torque multiplication.

The effect of the torque-amplifier on the transmission and final-drive-gear ratios is shown on Fig. 5. The normal or conventional first-speed ratio of the transmission is 6.68

Fig. 10 *(Upper Right)* The torque-amplifier clutch disassembled • **Figs. 11, 12, and 13** *(Upper Right, Lower Left and Right)* Component parts of the torque-amplifier gear train

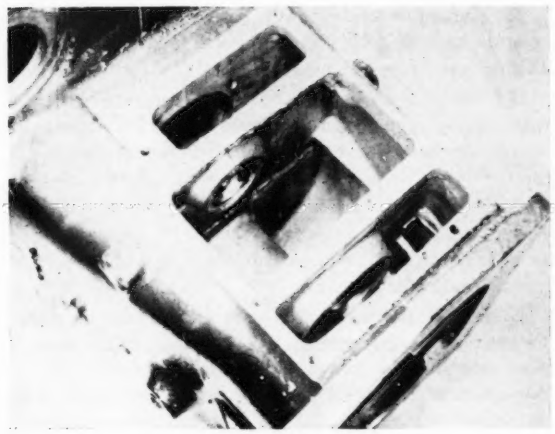


Fig. 14 The bare clutch housing

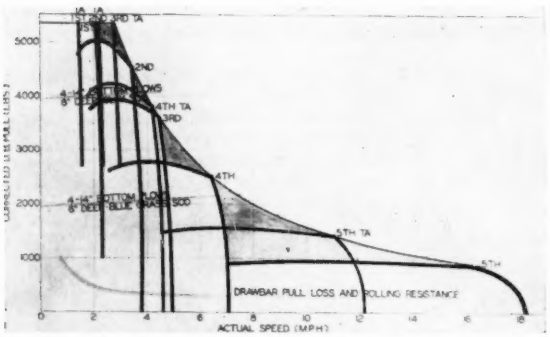


Fig. 17 Performance chart indicating greatly increased working ability of the torque-amplified tractor

to 1. When the operator shifts to TA, the engine torque is multiplied 9.9 to 1. Hence, with a fixed final-drive ratio of 14.8 to 1, the over-all transmission and final-drive ratio changes from 98.8 to 146.4 to 1. This large transmission and final-drive ratio provides a tractor creeper speed of 1.69 mph. In fifth speed, the torque-amplifier action provides a total over-all ratio of 21.9 to 1 to produce a 11.27-mph intermediate transport ground speed.

In order to appreciate more fully the simple, compact construction of the torque-amplifier and visualize the work done through these parts, the reader is referred to the following series of accompanying illustrations showing a disassembly of the clutch housing: Fig. 6 shows the complete clutch housing removed from the tractor, and Fig. 7 is a view of the engine master-clutch compartment. Fig. 8 gives a view of the clutch-housing with the top cover removed, and Fig. 9 shows the engine clutch-release mechanism disassembled. Fig. 10 shows the torque-amplifier clutch disassembled, and the component parts of the torque-amplifier gear train are shown in Figs. 11, 12, and 13. Fig. 14 is a view of the bare clutch housing.

The center or torque-amplifier clutch compartment is a dry pocket. The torque-amplifier as a planetary unit is lubricated with transmission oil in a double-circulatory system. The primary flow of SAE 80 oil is pumped from the bottom of the clutch housing by the independent power take-off front drive gears located ahead of the torque-amplifier

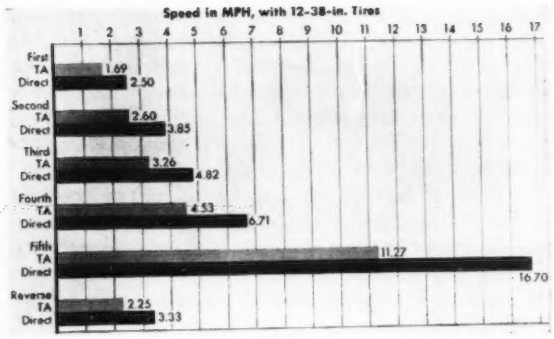

Speed in MPH, with 12-38-in. Tires
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
First TA 1.69
First Direct 2.50
Second TA 2.60
Second Direct 3.85
Third TA 3.26
Third Direct 4.82
Fourth TA 4.53
Fourth Direct 6.71
Fifth TA 11.27
Fifth Direct 16.70
Reverse TA 2.25
Reverse Direct 3.33

Fig. 15 Chart showing actual ground speeds of tractor with torque-amplifier drive

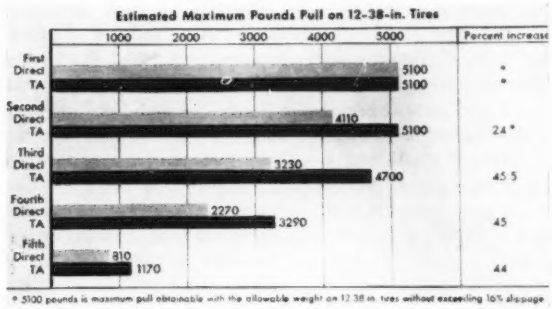

Estimated Maximum Pounds Pull on 12-38-in. Tires
1000 2000 3000 4000 5000
Percent increase
First Direct 5100
First TA 5100
Second Direct 4110
Second TA 5100 24 *
Third Direct 3230
Third TA 4700 45.5
Fourth Direct 2270
Fourth TA 3290 45
Fifth Direct 810
Fifth TA 1170 44
* 5100 pounds is maximum pull obtainable with the allowable weight on 12-38 in. tires without exceeding 16% slippage

Fig. 16 Chart showing pulling force of tractor at speeds shown in Fig. 15

clutch. This oil collects in a trough, drains through a gallery passage into the torque-amplifier compartment bowl, and overflows a dam to drain down into the bottom of the clutch housing. A second path of oil from the rear-frame left trough also pours into the torque-amplifier bowl. This added oil also overflows the dam and drains into the clutch housing seeking a level established by a hole in the mating flanges of the clutch housing and rear frame. This bowl-type circulatory system assures sufficient uphill lubrication as well as downhill oil clearance. Lip-type oil seals on the input sun gear and carrier keep the torque-amplifier clutch compartment dry.

Actual ground speeds of the new Farmall torque-amplifier tractor are shown in Fig. 15. The torque-amplifier drive

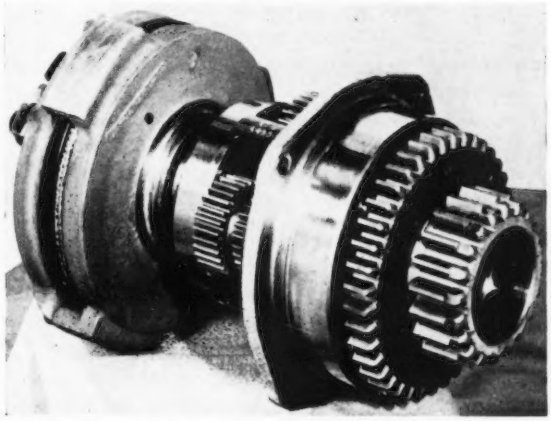


Fig. 18 The heart and muscle of the torque-amplifier drive

is designed to allow the operator to downshift to the next lower speed without interruption of power. It should be noted that two (2) new speeds of 1⅜ mph and 11¼ mph approximately are available for creeper and intermediate transport work, respectively. The pulling force at these speeds is shown in Fig. 16 indicating actual drawbar pull available at the wheels.

Fig. 17 is further indication of the greatly increased working ability of the torque-amplified tractor. Normal over-all tractor performance curves of each selected gear are displaced when operating in torque-amplifier to drive form new useable working areas bounded under the traction limitation line.

A working zone for heavy-duty plowing is also plotted on this performance chart to show how the torque-amplifier will assist in selecting more economical engine operating speeds. The following illustration indicates how the new torque-amplifier drive will plow up to two (2) more acres of work per day with less strain on the farmer. A Farmall Super M-TA tractor operating in third gear and pulling four 14-in bottom plows through 8-in deep clay soil may load the engine sufficiently and economically until the operator hits a spot in the field where the soil is hard and tough. When the engine begins to labor and lower its speed, the operator merely pulls the torque-amplifier hand lever back throwing the tractor into third torque-amplifier speed. This action allows the engine to immediately approach normal governed speed. However, when the hard spot in the field is passed, the operator releases the torque-amplifier hand lever allowing the tractor to return to direct drive so that the engine again operates at the more economical speed.

Fig. 18 shows the heart and muscle of the torque-amplifier drive. This device is strong and durable for a long working life in the field as thousands of test hours have already proven. The structure is basically simple in design and even serves as its own pump to lubricate the innermost bearings and gears. Even the torque-amplifier clutch adjustments are simple and easy at outside levers. The torque-amplifier action is fast and effective in changing tractor speed instantaneously on the go. The torque-amplifier drive has already justified its existence by proving that it will do more work per day and thereby provide greater profit for the owner.

Heat to Vaporize Moisture

(Continued from page 709)

may become low enough to provide exception to the preceding statement.

As drying progressed to lower moisture contents, further increases in the heat requirement were noted. At a grain moisture of 10 percent dry basis the heat requirement was about 15 to 20 percent above that for free water in the temperature range used in the drying tests.

Conclusions

The results obtained appear to justify the following conclusions:

1 The heat required for evaporation of moisture in wheat and shelled corn may be greater than the heat required for evaporation of free water depending on the magnitude of the hygroscopic effect at lower moisture contents.

2 The heat requirement is primarily a function of grain-moisture content and is not significantly dependent upon drying temperature and initial moisture.

3 Over the range of moistures encountered in most actual drying systems for wheat and shelled corn, above 14 percent dry basis, the heat required for vaporization is between 1.00 and 1.06 times that for vaporization of free water.

4 If drying is carried to moisture contents below 14 percent, the heat requirement is further increased; at a moisture content of 10 percent dry basis, it is about 1.15 to 1.20 times that for free water.

5 For calculations dealing with the moisture-time relation in most drying systems, the variation of heat requirement with moisture content is not sufficient to preclude the assumption of a constant value for this quantity, thus facilitating such analysis.

BIBLIOGRAPHY

1 Argue, G. H., and Maass, O., Measurements of the heats of wetting of cellulose and wood pulp, *Canadian J. Res.* 12 : 564 (1953).

2 Babbitt, J. D., On the adsorption of water vapor by cellulose, *Canadian J. Res.* 20A : 143 (1942).

3 Gallaher, G. L., A method of determining the latent heat of agricultural crops, AGRICULTURAL ENGINEERING 32 : 34 (1951).

4 Gay, F. J., Effect of temperature on moisture content—equilibrium of wheat, *Journal Council for Scientific and Industrial Research* (Australia), 19 : 187-89 (1946).

5 Glasstone, Samuel, Thermodynamics for chemists, New York, D. Van Nostrand Co. (1947).

6 Gregory, R. M., Heat requirements in the removal of hygroscopic moisture in wheat, unpublished thesis, Purdue University (1951).

7 Henderson, S. M., A basic concept of equilibrium moisture, AGRICULTURAL ENGINEERING 33 : 20-32 (1952).

8 Kretovich, V. L., Physiologico—biochemical basis for the storage of wheat. Translation from Russian by K. Stan Chester. Izdatrlstvo Akademii Nauk USSR (1945).

9 MacMasters, M. M., Grain structure and grain storage, Bureau of Agricultural and Industrial Chemistry, Bul. 348, U.S. Dept. of Agr. (1953).

10 Newsome, P. T., and Sheppard, S. E., The sorption of water vapor by cellulose and its derivatives," *J. Phys. Chem.* 36 : 930 (1932).

11 Othmer, Donald F., Correlating vapor pressure and latent heat data, *Jour. of Ind. and Engr. Chem.* 32 : 841-56 (1940).

12 Page, G. E., Factors influencing the maximum rates of air drying shelled corn in thin layers, unpublished thesis, Purdue University (1949).

13 Thompson, H. J., Moisture equilibrium studies on grains, unpublished report. Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S. Dept. of Agri. (1953).

Engineering Ethics

WHEN engineering employers habitually and regularly insist that engineers shall know their ethics, just as they insist that engineers shall be technically competent, they will have gone a long way toward giving engineers professional standing. Then, and not until then, will engineers enjoy the professional standing of physicians and lawyers in the employ of corporations.

Once the employer has given his engineers full professional standing, he can safely discard the countless rules and regulations of the familiar employees' handbook, as far as his engineers are concerned.—Clement J. Freund in *Midwest Engineer* for August, 1954.

Friction Loss in Aluminum Pipe

Harold E. Gray, Gilbert Levine, M. Bogema
Member ASAE Assoc. Member ASAE

Report on Results of Tests to Develop More Accurate Formula for Determination of Friction Loss

FOR a number of years the design of portable irrigation mains and laterals has been based upon the friction loss as computed by Scobey's formula:

$$H_f = \frac{K_s L V^{1.9}}{1000 D^{1.1}} \quad . \quad . \quad . \quad . \quad . \quad . \quad [1]$$

where H_f = friction loss in feet
L = length of pipe in feet
V = mean velocity in feet per second (fps)
D = internal diameter in feet
K_s = friction coefficient determined by experiment.

This formula was developed by Scobey from studies made of welded steel and analogous pipe.

The application of Scobey's formula to portable irrigation pipe was suggested by Christiansen (1)*. Values of K_s of 0.34 for 2-in pipe, 0.34 for 2½-in pipe, 0.33 for 3-in pipe and 0.32 for 4-in, 5-in and 6-in pipe (16 and 18 gage) were suggested.

With the development of aluminum pipe for use as portable irrigation lines, designers have continued to use Scobey's formula, with slight modifications in the values of K_s. As a typical example one manufacturer gives values of K_s of 0.34 for 2-in aluminum pipe, 0.33 for 3-in and 0.32 for other sizes. For portable aluminum pipe with couplers a value of 0.40 is suggested for main lines to account for the extra loss caused by the couplers (2).

During the course of a recently completed comprehensive study of friction losses in aluminum couplers, determinations were made of the friction loss in the pipe itself. Preliminary determinations indicated that the application of Scobey's formula to aluminum irrigation pipe was not strictly correct. A more complete study was conducted and is the subject of this paper.

Test Equipment and Procedure

Two 20-ft lengths of 3-in aluminum pipe were selected from a stock of pipe which had three seasons of use in pasture irrigation experiments. The two lengths of pipe were installed in a tandem arrangement as shown in Fig. 1. Flow of water was obtained by an electrically driven centrifugal pump. Flow rates were measured by the use of a calibrated orifice. Flow was controlled by a gate valve upstream from the orifice.

An 8-ft section in each pipe was chosen as the test section. Each test section was preceded by a straight pipe section 38 diameters in length, and followed by a straight pipe section 10 diameters in length. These distances resulted in uniform flow conditions through the pipe test sections.

Manometer taps were installed in the pipe and connected to a multiple-tube water manometer; all pressure readings at a given flow rate could be made simultaneously. Readings for each test section were taken at 20 flow rates. Two sets of 20 flow rates in the same range were obtained, each by a different individual. The data from the two sets were combined for each length of pipe.

Flow rates were converted to mean velocity using an inside diameter of the pipe of 2.9 in. Velocities ranged from 2.58 to 7.30 fps (53 to 150 gpm). All flows were well within the turbulent range as evidenced by Reynolds numbers of from 48,200 to 136,400.

Experimental Results

The head loss in the pipe was plotted against velocity of flow. The equation for the head loss in each test section, as well as for the composite of the two, was determined by the method of least squares. These equations established the following relations:

$$\text{Upstream pipe} - H_f \propto V^{1.71} \quad . \quad . \quad . \quad . \quad . \quad [2]$$

$$\text{Downstream pipe} - H_f \propto V^{1.77} \quad . \quad . \quad . \quad . \quad . \quad [3]$$

$$\text{Composite data} - H_f \propto V^{1.74} \quad . \quad . \quad . \quad . \quad . \quad [4]$$

The statistical analysis of the data showed that the upstream pipe differed significantly from the downstream pipe with respect to head loss. From a practical standpoint this difference is not important, but it points out the precision with which the measurements were made.

From the above results, and by accepting the principle of dimensional analysis, i.e., that the sum of the exponents of velocity and pipe diameter is a whole number (in this case three), formulas can be written in the general form of the Darcy equation as follows:

$$\text{Upstream pipe} - H_f = .30 \frac{L}{1000} \frac{V^{1.71}}{D^{1.29}} \quad . \quad . \quad [5]$$

$$\text{Downstream pipe} - H_f = .30 \frac{L}{1000} \frac{V^{1.77}}{D^{1.23}} \quad . \quad . \quad [6]$$

$$\text{Composite} - H_f = .30 \frac{L}{1000} \frac{V^{1.74}}{D^{1.26}} \quad . \quad . \quad [7]$$

where H_f is the loss in feet in a pipe of length L, and the coefficient shown is based upon 1000 ft of pipe.

Discussion of Results

The first question that arises as a result of this investigation concerns the difference between the observed results and the Scobey formula. An analysis by Blasius has shown that for hydraulically smooth pipe, between Reynolds

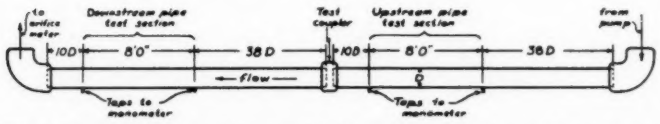


Fig. 1 Schematic diagram of test setup for determining friction loss in aluminum pipe

Paper prepared expressly for AGRICULTURAL ENGINEERING. This is the first of two articles on the subject of friction loss in aluminum irrigation mains and laterals. The second article, reporting a recently completed comprehensive study of friction losses in aluminum couplers, will appear in the next issue.

The authors—HAROLD E. GRAY, GILBERT LEVINE, and M. BOGEMA—are, respectively, associate professor and assistant professor of agricultural engineering, and professor of hydraulics, Cornell University.

*Numbers in parentheses refer to the appended bibliography.

numbers of 3000 and 100,000, the value for friction factor, f, varies as follows (3):

$$f=0.316/N_R^{0.25} \quad [8]$$

If this is substituted in the Darcy equation, using appropriate values for the density and viscosity of the water, the following equation is obtained:

$$H_f=0.295\ (V^{1.75}/D^{1.25}) \quad [9]$$

Further evidence is presented by Schoder who proposed the following relationships (4):

For extremely smooth pipes (per 1000 ft)

$$H_f=0.30\ (V^{1.75}/D^{1.25}) \quad [10]$$

For fairly smooth pipe

$$H_f=0.38\ (V^{1.86}/D^{1.25}) \quad [11]$$

Shoder's description of the two categories of pipe are as follows:

> Extremely smooth pipes: New seamless-drawn brass, block-tin and lead, glass, porcelain-like glazed pipes; all with interior surfaces both appearing very even to the eye and feeling very firm and smooth to the touch.
>
> Fairly smooth pipes: All ordinary pipes after a few (say, about five, more or less) years in ordinary service, such as asphalt-coated cast iron and spiral-riveted steel pipes(latter of thin metal and with very flat rivet heads), wrought iron; both "black" and galvanized (but the latter in the small sizes may be "rough pipes" even when new), wood stave, reinforced concrete, galvanized, spiral-riveted steel.

Although aluminum pipe is not mentioned in either classification, the fact that most aluminum pipe is seamless extruded, together with its appearance would seem to indicate that it would fall in Schoder's classification as "extremely smooth pipe," which is similar to Blasius' hydraulically smooth pipe. This coupled with the close agreement of the test results with the Schoder equation would indicate that the Scobey formula is not exactly correct for the aluminum pipe.

Galvanized-steel irrigation pipe closely approximates Schoder's description of fairly smooth pipe and, considering the similarity of his equation and Scobey's formula, it would seem that the latter is applicable to this type of pipe.

A graphical comparison of the two equations and the test results is shown in Fig. 2. Head loss in feet per 1000 ft is plotted against velocity for the test results, Schoder's formula for extremely smooth pipe and Scobey's formula with a K_s of 0.33 (value used for 3-in pipe). Obviously, the test results are so close to Schoder's formula that they can be considered to be essentially the same. Scobey's formula, on the other hand, shows greater head loss at a given velocity than the other two. This loss does approach the test results at the lower velocities (50 to 55 gpm); however, these velocities are much lower than those that the pipe would normally be designed to carry. At a velocity of 7 fps (approximately 150 gpm), Scobey's formula gives a head loss of about 10 ft higher per 1000 ft of pipe than the Schoder equation or the test results.

From a practical design standpoint, this discrepancy may not be important. From a scientific viewpoint, however, it has value since an equation is available that will more closely describe the observed results. In addition, if the head loss in the straight pipe were to be used as a reference, the use of the Scobey formula would cause proportionately larger errors. Data from the coupler-loss tests can be used to illustrate the magnitude of this error.

At a flow rate of 4.8 fps (approximately 100 gpm) the head loss per foot of 3-in pipe, using Scobey's formula, is 0.031 ft. The excess head loss due to one of the couplers tested was 0.084 ft. The resulting equivalent length of pipe is 2.7 ft. Using the equation suggested in this paper we calculate a straight pipe head loss of 0.028 ft and an equivalent length of pipe of 3.0 ft; the difference between the results of the two equations is on the order of 10 percent. Furthermore, at a velocity of 7.0 fps (approximately 145 gpm), the equivalent length using Scobey's formula is 2.5 ft, while for the proposed equation it remains at 3.0 ft. The difference is now about 17 percent. The Scobey equation results in a decrease in the equivalent length of pipe as the velocity increases, and gives a different equivalent length for each flow rate.

CONCLUSIONS

Results of tests on friction loss in 3-in aluminum pipe indicate that this pipe should be classed as Schoder's "extremely smooth pipe" or Blasius' "hydraulically smooth pipe" for determining friction loss.

The formula developed from these tests is essentially the same as that given by Schoder and is as follows:

$$H_f=.30\frac{L}{1000}\frac{V^{1.74}}{D^{1.26}}$$

The Scobey formula now generally used is not exactly applicable to aluminum irrigation pipe.

There is need to conduct experiments upon other sizes of pipe to verify the effect of diameter. In addition, the effect of "aging" on aluminum pipe should be studied.

BIBLIOGRAPHY

1 Christiansen, J. E.: Irrigation by sprinkling, California Agricultural Experiment Station Bulletin 670, October, 1942.

2 Sprinkler Irrigation Handbook: Rainbird Sprinkler Manufacturing Corp., Glendora, Calif., 1952.

3 Vennard, J. K.: Elementary fluid mechanics, John Wiley and Sons, New York, 1947.

4 Schoder, E. W. and Dawson, F. M.: Hydraulics, McGraw-Hill Book Co., New York, 1934.

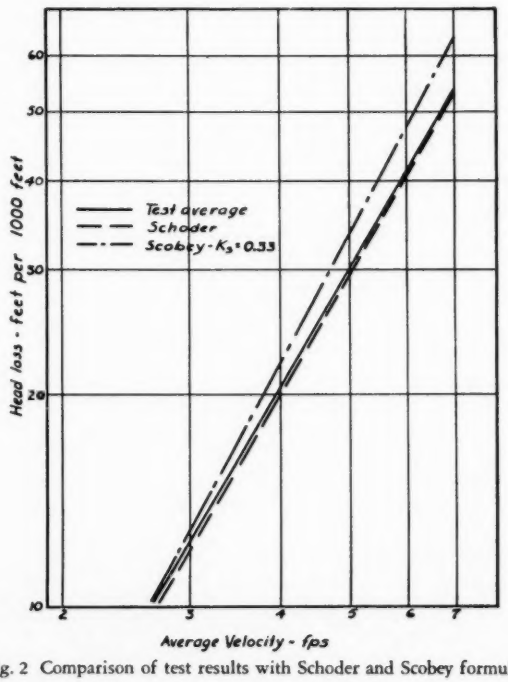


Fig. 2 Comparison of test results with Schoder and Scobey formulas

Practical Aspects of Draintile Durability

Some Recommendations for Draintile Subject to Freezing, Alkali, or Acid Conditions

P. W. Manson and D. G. Miller
Member ASAE Fellow ASAE

THE purpose of this paper is to acquaint the agricultural engineer with the practical aspects of draintile durability. These conclusions are the results of extensive research conducted at the University of Minnesota during the past 35 years as recorded in the four principal publications (1, 2, 3, 4).*

Freezing and Thawing Action

Clay tile are resistant to the action of both soil acids and soil alkalies but unless of good quality will deteriorate from frost action. Exact data are meager as to depth and frequency of frost penetration in farm fields. It is a known fact that many clay draintile of low quality have failed which have been installed with a soil cover of less than 2 ft in the colder regions of the United States. It is poor practice to leave clay tile lay on the ground over winter. Even fairly soft clay tile will give many years satisfactory service if in first-class condition when placed in ditches with a soil cover of 2 ft or more.

In latitudes where freezing and thawing action is not much of a problem, it should be kept in mind that high-absorption clay products are rarely high-strength products. This is important in the drainage field as the present trend is to install tile relatively deep in machine-dug ditches considerably wider than those formerly dug by hand. Furthermore, the use of heavier farm machinery has increased the superimposed load factor. In keeping with good engineering practice, the emphasis, therefore, is certain to be toward a demand for stronger tile. Fortunately, use of stronger tile will almost automatically bring about the use of tile lower in absorption and in turn higher in frost resistance.

Action of Soil Alkalies

Where the soil alkalies contain sodium or magnesium sulfate, singly or in combination, in quantities in excess of 3000 ppm (0.30 percent), the soil or soil water in contact with concrete draintile should be assumed to be deleterious and extra precautions should be taken.

Observations and tests of many specimens have shown convincingly that in the design of concrete mixes for maximum durability under sulfate exposure conditions, the primary consideration must be low permeability, usually a corollary of high unit strength.

It is in the field of cement chemistry where by far the greatest progress has been made in the improvement of the performance of concrete exposed to soil sulfates. The importance of the chemistry of the cement has been shown so many times that it is now accepted as a fact, and standard specifications have been prepared for sulfate-resisting portland cements in both the United States and Canada, the essential provision being maximum limitation on the percent of the calculated compound tricalcium aluminate ($3CaO \cdot Al_2O_3$), commonly abbreviated (C_3A). Based on the many tests reported on the Minnesota work, the permissible limit for C_3A should not exceed 5.5 percent. Type V cement of the American Society for Testing Materials is such a sulfate-resistant cement as is frequently Type II cement.

Few admixtures used at Minnesota increased sulfate resistance; most had little or no effect while some were deleterious. High-temperature stream curing, 212 to 350F, proved to be an extremely effective means of increasing the sulfate resistance of concrete. As yet high-temperature steam-cured draintile have not been manufactured on a commercial basis.

Action of Soil Acids

Practically all concrete draintile so far examined have shown some evidence of corrosive action where exposed in peats with acidities indi-

Paper presented at the annual meeting of the American Society of Agricultural Engineers at Minneapolis, Minn., June, 1954, on a program arranged by the Power and Machinery Division.

The authors—P. W. MANSON and D. G. MILLER—are, respectively, professor and research associate in agricultural engineering, University of Minnesota.

*Numbers in parentheses refer to the appended bibliography.

TABLE 1. DRAINTILE QUALITY AS RELATED TO AGGREGATE GRADATION
(Note: All tile are of nominal wall thickness)

Crushing strengths (Sand bearing method), lb per linear ft			Absorption, percent			Sieve analyses of aggregates, percent coarser			
Extra quality	Standard quality	Below standard	Extra quality	Standard quality	Below standard	Sieve No.	Extra quality	Standard quality	Below standard
4-in	6-in	6-in	4-in	6-in	6-in		4-in	6-in	6-in
1570	1450	1100	6.0	9.4	11.6	3/4	0	0	0
1550	1300	1300	5.9	9.1	10.3	3/8	0	0	0
1620	1270	1100	6.9	9.4	11.0	4	26	20	1
1880	1370	990	5.7	10.1	11.5	8	40	34	12
2210	1270	810	6.3	9.9	14.1	16	50	45	26
1890	1690	1090	6.1	9.1	11.3	30	62	58	56
1450	1340	1140	5.8	10.0	11.9	50	86	84	88
2220	1490	1050	5.9	10.1	12.1	100	97	97	98
1740	...	1080	6.2	...	11.3	residue	3	3	2
1650	...	1230	5.8	...	...				
Avg. 1780	1400	1090	6.1	9.6	11.7	fineness modulus	3.6	3.4	2.8

TABLE 2. EXAMPLES OF SUITABLE MIXES FOR DRAINTILE

Standard draintile	Extra-quality draintile
Sizes, 5 to 8-in Cement 94 lb Concrete sand 265 " Pea gravel 68 " (F.M. - 3.4) (Mix is 1 to 3½ by weight)	Sizes, 5 to 8-in Cement 94 lb Concrete sand 210 " Pea gravel 73 " (F.M. - 3.6) (Mix is 1 to 3 by weight)
Extra quality recommended for sizes 10 in and larger	Sizes, 10 to 12-in Cement 94 lb Concrete sand 188 " Pea gravel 94 " (F.M. - 3.8) (Mix is 1 to 3 by weight)

cated by a pH value of 6.0 or less. In general, the degree of corrosion varied with the acidity of the peat and the length of the exposure period. Rich mixes of high strength and low permeability gave the greatest resistance to the action of soil acids. None of the admixtures or special procedures used at Minnesota appreciably improved the resistance of high-strength concrete.

All concrete draintile installed in peat should be of at least the quality required for extra-quality draintile of the standard specifications for draintile, ASTM designation C4-50T. Concrete in tile of this type will have a compressive strength of 4000 psi, or more, and an absorption of 8 percent or less .

Manufacture of Durable Concrete Draintile

The quality of clay tile largely depends on the characteristics of the raw clay or shale and the burning processes. Consequently the procedure for manufacturing clay tile is pretty well established for any one plant, and, as a result, a plant will consistently produce good or poor quality tile.

On the other hand, there are many details involved in the making of concrete tile which can be controlled by the producer. The requisites for the manufacture of high-quality concrete draintile on the ordinary "packer-head" machine are: *(a)* well-graded sound aggregates and sufficient cement, *(b)* maximum of mixing water, *(c)* ample compactness of the materials, and *(d)* adequate curing. These requisites will be briefly discussed in this paper as they are considered in detail in the reference (4) noted above.

Well-Graded Sound Aggregate and Sufficient Cement

For all practical purposes the principal requirement of good grading for draintile of the smaller diameters may be expressed briefly as not much less than 40 percent retained on the No. 8 sieve with preferably somewhat more than half of this 40 percent retained on the No. 4 sieve. Without a high proportion of these coarser particles in the mix it will be extremely difficult to produce draintile which will be low enough in absorption to meet the requirements of ASTM C4-50T. The effects on absorption of variations in the aggregates gradation are shown by the tests recorded in Table 1.

At best the proportion of the coarser particles in aggregates suitable for thin-walled tile will always be lower than that which theoretically would produce maximum strength. The mixes and aggregate combinations of Table 2 are essentially those used at a number of commercial plants in the Middle West which manufacture well-made draintile. Note that the mixes for "extra-quality" and "standard" tile differ chiefly in that the proportions of both cement and pea gravel are increased for "extra-quality" tile. It is difficult to manufacture draintile of the smaller diameters which will be consistently high in strength and low in absorption unless they are made with rich mixes even though the aggregate grading is as coarse as recommended.

Once the mix has been determined that produces tile which meet strength and absorption requirements, the yield in the number of tile of the same size per batch becomes a measure of uniformity of output. On the basis of the mix of Table 2, the maximum yield in tile per sack of cement may be expected to be about as follows:

Tile			Number of feet of tile per sack of cement	
Diameter	Wall thickness	Approx. weight per ft	Standard quality	Extra quality
5 in	9/16 in	10 lb	41	36
6 in	5/8 in	14 lb	31	27
8 in	3/4 in	22 lb	19	17
10 in	7/8 in	31 lb	—	12
12 in	1 in	45 lb	—	8½

Maximum Mixing Water

The tendency in making dry-tamped concrete products where the jackets are stripped immediately is to use too little water in the mix. Fig. 1 shows the appearance of tile made with well-graded aggregates and sufficient mixing water.

The total amount of mixing water, including any surface moisture in the aggregates, will not exceed about 3½ gal per sack of cement. However, it serves little useful purpose to express the quantity of mixing water on the accepted basis of gallons per sack of cement because the balance between the proper amount and too little is very narrow for tile of the smaller diameters made on packer-head machines. In practice, the usable water will be largely determined by the man at the mixer on the basis of apparent workability of each batch.

Ample Compaction of the Materials

Careful proportioning of the aggregates, cement and water does not insure high strength and low absorption draintile unless the resulting stiff mixture is thoroughly compacted when formed into draintile.

Draintile of the smaller diameters are usually made on a power-driven machine with a vertical shaft, on the lower end of which is attached a heavy metal cylinder assembly called a "packer head" consisting essentially of a "packer ring" or "troweling ring" on which are bolted adjustable "packer cheeks." It is these "cheeks" which compact the concrete materials against the jackets used to form the outside of the tile as the packer head revolves. A view of a packer-head assembly for 6-in tile is shown in Fig. 2.

(Continued on page 725)

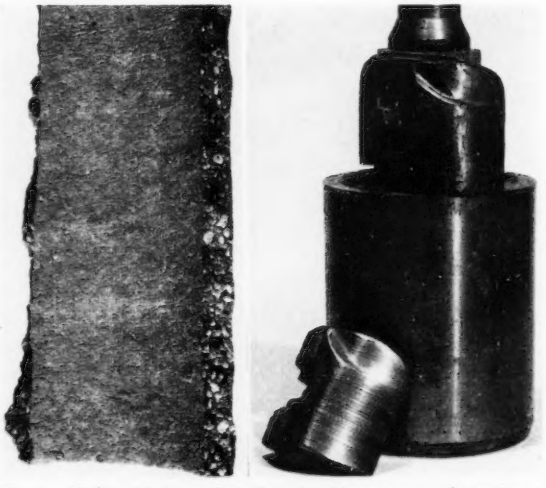


Fig. 1 *(Left)* Section of well-made 6-in concrete draintile • Fig. 2 *(Right)* Packer head and adjustable packer rings which form the inside of machine-made 6-in draintile

Estimating Infiltration

D. B. Krimgold and O. Beenhouwer
Member ASAE

General Values Based on Other Properties of Soils Are Offered for Use Only When Field Demonstration Is Impractical

INFILTRATION, the movement into and through the soil of water derived from rainfall, melting snow, and irrigation, is one of the determining factors in the moisture regimen of soils and is therefore of concern in many phases of hydrology. Quite naturally then, infiltration was one of the factors investigated in developing a method of estimating soil moisture in connection with military problems in tractionability.

Infiltration has been thought of and defined differently by various people, who have viewed it from the standpoints of: soil and moisture conservation—Musgrave (28)*, Kachinski (13), and others; irrigation—Lewis (23), Kostiakov (16), Mamanina (24), and others; flood control—Horton (9), Horner (7), Sherman (30), Cook (4), and others; and effects of vegetation on water yields of watersheds—Colman (3). The views and thoughts of various soil scientists on the movement of water into and through soils have been summarized by Baver in 1940 (1) and by Rode in 1952 (29).

Literally thousands of measurements have been made with various devices such as the sprinkling can used by Houk in his tests reported in 1921 (11), the ring infiltrometers used by Lewis (23) and later by Free *et al.* (6), and the elaborate rainfall simulators developed by the Forest Service and the Soil Conservation Service of the U.S. Department of Agriculture (27). Only a small fraction of the results of these numerous measurements was published. The efforts of most investigators were directed toward obtaining parameters, such as Horton's f_o, f_c, and K values (10), and Kostiakov's K_t (17), for various soil-vegetation complexes. Free *et al.* (6) and Kachinski *et al.* (14) have reported systematically the results of infiltration tests together with information on the various soil characteristics that could be expected to affect infiltration.

To be of greatest value any method for estimating soil moisture for use in solving military problems in tractionability should involve only readily available data. The specific task in the infiltration phase of the U.S. Air Force research contract was therefore to investigate the possibility of expressing infiltration in terms of known or readily determinable properties of soils.

Three Modes of Movement of Water Into and Through Soils

In estimating soil moisture, whether in connection with problems in tractionability, crop production with and without irrigation, drainage, runoff from small areas, or tillage, one must know how much of the precipitation falling on a field enters the soil and how rapidly the excess moisture moves through the soil. The first step is therefore to gain as clear an understanding as possible of the two phenomena, entrance of water into the soil and movement of water through the soil.

Soil can be thought of as a porous, fissured, vascular medium. All soils are porous but not all are fissured or vascular. Sandy soils, freshly prepared seedbeds, and freshly cultivated soils of any texture are not fissured or vascular. Uncultivated clay and clay loam soils are fissured when dry but not when wet. All soils with a dense vegetative cover, such as a grass sod, or with a forest litter are porous and vascular. Clay soils subject to excessive shrinkage and swelling develop wide deep cracks on drying.

For the general case three modes of movement of water into soils must be considered. The first is the flow through or filling of large cracks and large ducts such as animal burrows. The flow of water into such openings is so rapid that, under conditions of natural or artificial rainfall, it is limited only by the rate of rainfall. With unusually heavy precipitation falling on a soil with widely spaced cracks, water may accumulate on the areas between the cracks and might flow over the sides of the openings pretty much like over a weir or into a drop-inlet culvert. But even then the intensity of rainfall would be the controlling factor because the rate of flow into such wide cracks would exceed the rate of rainfall plus the rate of runoff from blocks between the cracks.

The second mode of movement of water into the soil is the flow through or filling of the smaller ducts. These are the worm holes and other channels of comparable size. The rate of flow into such openings depends on the net hydraulic head, on the shape and diameter of the opening, and the shape, diameter, and length of the duct. As a rough approximation the rate of flow, f, into and through such ducts can be expressed by

$$f = Cd^{5/2}(h/L)^{1/2}$$

In this expression d is the diameter of the duct, h is the hydraulic head, L is the length of the duct, and C is a constant which includes the acceleration of gravity, the entrance coefficient, and the friction coefficient which in turn is a function of the diameter, roughness, and the alignment of the duct. For any given instant d, L, and C remain constant and the flow is determined by h, which is a function of the vertical depth of water in the duct and above it. This depth is in turn a function of the intensity of rainfall. Under conditions of natural or artificial rainfall the capacities of such conduits become the limiting factor only when the rate of rainfall is quite excessive.

The third mode of movement is into the soil mass—that is, through the small and large pores. This movement can take place upward, downward, and laterally. In infiltration we are concerned with the latter two directions. The lateral movement is through the walls of cracks and ducts in

Paper presented at a meeting of the North Atlantic Section of the American Society of Agricultural Engineers at Burlington, Vt., August, 1954. The research reported in this paper has been made possible through support and sponsorship extended by the Geophysical Research Directorate of the Cambridge Field Station, A.M.C., U.S. Air Force, under Contract No. AF19(604)-193. It is published for technical information only and does not represent recommendations or conclusions of the sponsoring agency.

The authors — D. B. KRIMGOLD and O. BEENHOUWER — are, respectively, principal research scientist and research assistant, The Johns Hopkins University, Laboratory of Climatology, Seabrook, N. J.

*Numbers in parentheses refer to the appended bibliography.

the soil. This downward and lateral movement is governed largely by capillary forces. In the absence of entapped air, the rate of this movement in all soils except coarse sand is analogous to the rate of capillary rise, which is expressed approximately by

$$\frac{dH}{dt} = nKt^{n-1}$$

where H is the height of capillary rise, t is time from beginning of movement, n is a constant depending on the soil, and K is the capillary rise at unit time t. Results of laboratory experiments show n to be approximately 0.5 (29) for a number of soils.

The rate of lateral movement is not subject to all the reductions that apply to the inflow through the surface. It is not subject to reduction by compaction or by sealing and crust formation through impact and sorting action of raindrops. The results of observations made by Kachinski (12) of moisture penetration into a dry fallow clay soil after a 24-hr rain, as illustrated in Fig. 1, tend to support the above statement with regard to lateral movement. The irregular columns in Fig. 1 undoubtedly represent lateral movement of moisture from cracks which were subsequently sealed by swelling. It is interesting to note that the horizontal distances from the centers of these irregular columns to the boundaries of the wetted soil are greater than the vertical wetted distances from the surface of the soil.

The movement of water in soils governed by capillary forces is greatly restricted in very coarse and in very fine-textured materials. In very coarse sand and in gravel capillary rise H is negligible. In such material infiltration takes place largely by gravity. In dispersed fine-textured soils both the capillary rise and infiltration are slow, because the pores are very small and the capillary forces are barely sufficient to overcome friction.

With these concepts of movement of water into and through soils one would expect to find quantitative relationships for soils without large cracks or ducts, or after such cracks have been filled or sealed. The number, sizes, and shapes of cracks and ducts in a soil do not lend themselves to quantitative treatment. For uncracked soils one would expect the expression for rates of infiltration to be of the same type as that for capillary rise. One would also expect a relationship to some soil characteristics that reflect the amount and quality of the pore space.

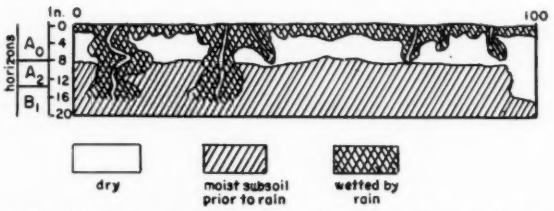


Fig. 1 Moisture penetration in dry clay soil after a 24-hr rain. (After Kachinski; outlines of cracks drawn in by authors)

Infiltration, Quantitative Relationships

The data on infiltration and soil characteristics reported by Free *et al* (6) for 68 sites representing 39 soil series and six of the great soil groups afforded an opportunity to investigate the existence and nature of such a relationship. Very briefly the procedure used by these authors was as follows. Infiltration in surface inches at 15, 30, 60, 120, and 180 min after the start of each run were obtained by the tube method. Galvanized-steel tubes 9 in in diameter were jacked into the soil so that they protruded 2 to 3 in above the soil surface. The tubes were 18 or 24 in long depending on the length required to penetrate into the subsoil. A head of about ¼ in of clear water was maintained in the tubes by self-dispensing burettes. Twenty-four replicates were used on each site.

An initial determination of infiltration rates was made at whatever field moisture content prevailed at the time, and a succeeding determination was made on the same units 24 hr later. These were referred to as "initial" and "wet" runs, respectively. Whenever feasible, the sites were in fields on which row crops were growing. These fields were not recently cultivated, and the ground was in settled condition. If such areas were not available, the sites selected were on fields of small grain or similar crops. The standard procedure was to remove all vegetal cover and ground litter on the soil surface confined by the tubes, with no disturbance of the soil itself.

The total porosity of the soil was computed by the formula, porosity $= (S-A)/S \times 100$, where S = specific gravity and A = field-volume weight. Non-capillary porosity indices were computed by *(a)* subtracting the moisture equivalent (converted to volume basis) from total porosity, *(b)* same as method *(a)* with moisture equivalent corrected for texture, and *(c)*

TABLE 1. COMPARISON OF OBSERVED AND COMPUTED INFILTRATION VALUES
(For soils with $\underline{n}$ = 0.75)

Soil	Non-capillary porosity	Accumulated infiltration (inches at t minutes after start of run)									
		15 min		30 min		60 min		120 min		180 min	
		obs	cmpt	obs	cmpt	obs	cmpt	obs	cmpt	obs	cmpt
(1) $\underline{F} = 1.93 \times 10^{-6}\ \underline{p}^{3.1}\ \underline{t}^{0.75}$											
Ruston sandy loam	35.5	1.01	0.95	1.52	1.59	2.41	2.68	4.17	4.53	5.94	6.16
Orangeburg sandy loam	32.7	0.76	0.73	1.23	1.22	1.98	2.06	3.47	3.49	4.85	4.73
Hopi sandy loam	32.4	0.65	0.70	1.04	1.18	1.75	2.00	3.31	3.36	5.00	4.56
Muskingum silt loam	30.1	0.72	0.57	1.04	0.96	1.66	1.60	2.88	2.70	4.12	3.65
Tama silt loam	27.1	0.48	0.40	0.73	0.68	1.22	1.13	2.17	1.92	3.11	2.60
Davidson clay loam	25.1	0.33	0.32	0.50	0.54	0.78	0.91	1.30	1.53	1.82	2.07
Vernon fine sandy loam	24.2	0.32	0.28	0.52	0.47	0.83	0.80	1.41	1.34	1.96	1.82
Vernon very fine sandy loam	23.4	0.29	0.25	0.45	0.43	0.74	0.72	1.33	1.20	1.84	1.63
Bates very fine sandy loam	22.8	0.31	0.24	0.44	0.40	0.65	0.68	1.06	1.13	1.44	1.54
Boone silt loam	22.5	0.29	0.23	0.43	0.39	0.65	0.65	1.05	1.09	1.41	1.48
(2) $\underline{F} = 3.14 \times 10^{-6}\ \underline{p}^{3.1}\ \underline{t}^{0.75}$											
Palouse silt loam	32.0	1.08	1.12	1.77	1.89	3.02	3.20	5.18	5.40	7.27	7.32
Austin clay	28.7	1.32	0.80	1.79	1.35	2.67	2.27	4.43	3.82	6.21	5.20
Carrington silt loam	28.2	0.76	0.75	1.18	1.26	1.97	2.11	3.46	3.56	4.88	4.82
Crown sandy clay loam	27.7	0.73	0.72	1.10	1.21	1.73	2.05	3.03	3.46	4.45	4.70
Athena silt loam	26.7	0.75	0.63	1.18	1.06	1.73	1.78	2.63	3.00	3.45	4.08
Pinedale clay loam	25.3	0.48	0.53	0.81	0.90	1.36	1.51	2.36	2.54	3.36	3.45
Fremont gravelly silt loam	22.7	0.50	0.39	0.79	0.66	1.25	1.10	2.16	1.84	3.02	2.50
Kirkland fine sandy loam	19.5	0.26	0.24	0.41	0.41	0.64	0.70	1.08	1.17	1.54	1.59
Cecil sandy loam	17.7	0.20	0.18	0.37	0.30	0.66	0.50	1.09	0.85	1.49	1.15
(3) $\underline{F} = 2.06 \times 10^{-11}\ \underline{p}^{6.2}\ \underline{t}^{0.75}$											
Honeoye gravelly silt loam	35.0	0.53	0.59	0.90	0.99	1.71	1.66	3.08	2.80	4.41	3.80
Muskingum silt loam	31.0	0.36	0.28	0.54	0.47	0.86	0.79	1.48	1.32	2.09	1.80
Palouse silty clay loam	30.5	0.27	0.24	0.42	0.41	0.68	0.70	1.15	1.17	1.62	1.59
Palouse silt loam	29.4	0.19	0.20	0.32	0.33	0.56	0.56	1.00	0.95	1.43	1.28
Clinton silt loam	27.8	0.17	0.14	0.27	0.24	0.46	0.40	0.83	0.67	1.18	0.91
Houston clay	26.6	0.12	0.11	0.16	0.18	0.24	0.30	0.38	0.51	0.56	0.69

subtracting from the total porosity the volume of water in the soil 24 hr after the initial run. Texture classifications were based on field identification by a soil specialist.

The mean and standard error for the cumulative amounts of infiltration at each time interval were computed for each site. Variation in infiltration between the twenty-four replicates was large in most cases, as is evidenced by the standard error reported for individual determinations.

Free, Browning and Musgrave, and Lewis before them, found that accumulated infiltration F at the end of any period t from beginning of application of water could be expressed by

$$F=at^n$$

For the initial runs Free *et al.* found a to vary from 0.0087 to 1 and n from 0.04 to 0.82.

The first step in the present analysis was to ascertain whether any of the 68 sites fell in groups having the same or nearly the same values of n. In such a group the change with time in rate of infiltration would be the same for all soils and the amount of infiltration at any time t would be proportional to individual values of a. Infiltration could conceivably be predicted from values of a and n expressed in terms of some measurable properties of soils. The value of n might perhaps reflect soil characteristics whose influence on infiltration changes with time and values of a other characteristics whose influence does not change with time.

The values for the initial runs fell in five groups, with values of n of 0.81 for 9 soils, 0.66 for 17 soils, 0.52 for 10 soils, 0.26 for 15 soils, and 0.12 for 7 soils. Ten of the soils did not fall in any group. There was no apparent significance to the several values of n nor was there any quantitative relationship found between the values of a in each slope group and non-capillary porosity, the soil characteristic which, according to Free *et al.*, gave the best correlation with infiltration. The apparent lack of a quantitative relationship was to be expected because the dry runs did not represent comparable conditions for the various soils. The moisture content, which is an important factor, was not equivalent for all the soils. Also, some of the heavier, dry soils may have been fissured while others were not. Therefore, no extensive studies were made of dry-run values.

A better relationship was expected for the wet runs, which represent more uniform moisture conditions. In the analyses of the wet-run data 19 sites with amounts of infiltration at 15 min, $F_{15}<0.05$ in and at 180 min, $F_{180}<0.25$ inch were excluded. This was done because such low values were too close to the expected experimental error to be of much value in establishing quantitative relationships. Also excluded were the two sites in dense sod, so that the data included in this analysis represented essentially cropland only (cultivated crops and grain). Of the 47 sites included in the analysis the infiltration for 32 was represented by $F=At^n$, with $n=0.75$. It is perhaps no mere coincidence that we found $n=0.77$ for eight of the soils in Central Chernozen Belt of the USSR reported by Mamanina (24) and $n=0.70$ for several of the soils reported by Kachinski (14).

No relationship between the values of a and non-capillary porosity, p was found for 7 of the 32 soils with $n=0.75$. For the remaining 25 soils ranging in surface texture from clay to sandy loam, this relationship was represented by the following three equations:

$$a=1.93\times10^{-6}\ p^{3.1} \quad . \quad . \quad . \quad . \quad . \quad . \quad [1]$$

$$a=3.14\times10^{-6}\ p^{3.1} \quad . \quad . \quad . \quad . \quad . \quad . \quad [2]$$

$$a=2.06\times10^{-11}\ p^{6.2} \quad . \quad . \quad . \quad . \quad . \quad . \quad [3]$$

Equation [1] applied to 10 soils with a values ranging from 0.031 to 0.116, equation [2] represented 9 soils with a range in a from 0.030 to 0.141, and equation [3] covered 6 soils with a values from 0.0115 to 0.081. A comparison between computed and observed amounts of infiltration at 15, 30, 60, 120, and 180 min are shown in Table 1. This table shows rather wide differences in infiltration for soils with the same texture and presumably the same non-capillary porosities of the surface soil. The determinations of both texture and non-capillary porosity were admittedly quite rough and the reliability of the infiltration values may not be very high. Yet the differences in infiltration can be ascribed only partly to the shortcomings of the data. One should indeed expect appreciable differences between soils with the same texture and non-capillary porosity of the surface soil, even if these were determined quite accurately. Such differences can be due to the following factors: swelling and sealing of the surface soil; variation with the depth in texture, aggregation and non-capillary porosity. The data reported by Free *et al.* were apparently not adequate to express these additional factors quantitatively.

An attempt was made to relate values of a in the infiltration equation $F=at^n$ to other characteristics of the surface soil including volume weight, total porosity, aggregates >0.2 mm, field capacity, organic matter, silt and clay particles <0.5 mm, and clay particles <0.002 mm. Relation between a values and the following was also investigated: the ratio of non-capillary porosity of the surface soil and volume weight of the subsoil, and the ratio of non-capillary porosity times volume weight of the surface soil and volume weight of the subsoil. Use of these factors did not result in an expression common to all sites with $n=0.75$. It was noted that the temperature of the water used in making the wet runs ranged from 37 to 96 F. Such a wide range could conceivably affect the values of infiltration. Allowing for this factor did not change the picture.

The infiltration tests were made with clear water. Values therefore do not reflect the resistance of aggregates in the surface soil to the impact of raindrops or the sorting action of intense rainfall, both of which tend to seal the soil. Free *et al.* compared values of clear water with those obtained with rainfall simulators and with turbid water for some 13 soils with a range in rate of infiltration during the third hour from 0 to 3.08 iph. These soils included 3 sandy loams, 1 stony silt loam, 3 gravelly silt loams, 1 silt loam, 2 loams, 1 silty clay loam, and 2 clay loams. Free *et al.* used the ratio of the infiltration with turbid water to the infiltration with clear water to correct the clear water runs for turbidity. A plot of the corrected values against the clear water values showed the following approximate relationship:

$$y=0.545\ x^{0.905}$$

where y is the infiltration with turbid water and x the infiltration with clear water. For all practical purpose one is about one-half of the other. This agrees fairly well with what Dolgopolova (5) found in comparing infiltration

values obtained with clear water and with simulated rainfall. The nearly constant ratio for the range represented by the 13 soils afforded no means for differentiating between the effects of the impact and sorting action of raindrops.

Thus quantitative relationships between infiltration and non-capillary porosity were found for only 25 of the 47 soils analyzed. For the 25 soils three equations were required to express this relationship properly. Yet we cannot be sure that the relationships represented by the equations for the infiltration values are entirely fortuitous. The results of these studies strongly suggest that infiltration can be expressed in terms of measurable soil characteristics. The problem is to find adequate quantitative terms for such characteristics as porosity, pore size distribution, stability of aggregates, swelling, and for their variations with depth.

Surface Texture and Infiltration

The investigation reported in this paper did show beyond doubt that it is absolutely unrealistic and quite misleading to assign values of infiltration on the basis of surface texture alone. Rates of infiltration such as 2 iph for sand, 1 iph for sandy loam, 0.5 iph for loam, and 0.2 iph for silt and clay loam are frequently cited and widely used in the design and operation of irrigation systems. To demonstrate how misleading such values can be, some of the infiltration rates reported by Free *et al.* for crop land (cultivated or grain) are shown in Table 2.

In connection with the values in Table 2, it is well to remember that in all cases all vegetal cover and ground litter were removed before the runs were made. The values of infiltration are for clear water. They do nevertheless show the wide differences in infiltration for soils with the same surface texture.

It is quite obvious that rates of infiltration assigned on the basis of surface texture alone should not be used in such undertakings as the design and operation of costly irrigation systems when directly applicable values can be obtained on individual fields at a cost which is insignificant in relation to the savings that such information would afford. Infiltration values can be obtained at the same time and with essentially the same simple equipment as is required to obtain "field capacity". Rates of infiltration, field capacity, effective root zone, and the volume-weight ratios needed to convert moisture in percent-by-weight into depth-in-inches are of such great importance in the design and operation of irrigation systems and are so variable that to guess at them is, to put it mildly, quite unwise.

Physiographic, Geologic, and Pedologic Considerations

There are, however, other practical problems in the solution of which use of general values of infiltration must be resorted to because field determinations are either impractical or impossible. Such problems include estimating of economic feasibility of irrigation (21) and of tractionability in connection with over-all strategic military planning, determining flood frequencies, planning drainage projects, fitting of cropping plans and crop rotation to soil moisture and climatic conditions. Because the solution of all such problems involves analyses of probabilities, the tolerances in estimated values of infiltration need not be so narrow as for the design and operation of irrigation systems or for the planning of specific tillage operations at a given time. But even such wider tolerances do not justfy the selection of infiltration rates on the basis of texture alone.

Other criteria must be used in arriving at satisfactory general infiltration values. In seeking such criteria, the authors were guided by the following: the data reported by Free *et al.* for 68 sites in the United States and related information for these soils from other sources (15, 25, 32); similar data for 26 soils of the Central Ural Region of the USSR by Kachinski *et al.* (14) and for 8 Chernozem and Liesostep soils of the Central Chernozem Belt of the USSR by Mamanina (24); miscellaneous information on infiltration contained in various published and unpublished reports (27); numerous (largely unpublished) records of runoff from small drainage basins together with the detailed soil and topographic maps of some one hundred experimental watersheds (18, 20, 22).

Study of this material led to the conclusion that even general values of infiltration must be arrived at with due consideration of vegetative cover and must be based on the following physiographic, geologic, and pedologic factors:

(a) The element of relief occupied by the soil (upland, slope, bottomland, depressions)

(b) The parent material (loess, glacial till, stratified drift, claybeds, sandstone, shale, etc.)

(c) The soil-forming process (podzolization, calcification, laterization, etc.)

(d) The depth to the impeding stratum.

Relief, both because of its profound effect on the soil-forming process and because of the lateral gradient it gives to the soil mantle, has a determining influence on the movement of water through the soil and therefore on infiltration. Thus the infiltration of a gray-brown podzolic gravelly silt loam on glacial till occupying sloping land may be more than twice that of the same soil occupying low-lying depressions.

Soils on approximately the same relief may have quite different infiltration if the parent material is not the same. Muskingum silt loam, a gray-brown podzolic residual soil with rolling topography derived from sandstone, has an infiltration several times that of the same soil on the same relief but derived from shale.

For the same relief and parent material the movement of water into and through the soil is highest for the highly leached lateritic soils (red soils of the subtropical and trop-

TABLE 2. INFILTRATION AND TEXTURE OF SURFACE SOIL

Soil name and texture	Average infiltration rate, inches per hour		Cover and month of test
	1st hour of initial run	3rd hour of wet run	
Honeoye gravelly silt loam	6.92	4.96	oats and barley, July
Fremont gravelly silt loam	2.81	0.86	buckwheat, August
Ruston sandy loam	8.51	1.77	fallow, February (cotton previous year)
Cecil sandy loam	1.97	0.40	fallow, February (sorghum previous year)
Red Bay loam	2.23	0.38	fallow, March (cotton previous year)
Selah loam	1.24	0.11	fallow, May
Palouse silt loam	4.61	2.09	wheat, June
Walla Walla silt loam	0.71	0.06	wheat, June
Aiken clay loam	6.87	3.98	orchard, small grain and vetch, May
Cecil clay loam	1.46	0.01	rye, November

TABLE 3. SUGGESTED GENERAL VALUES OF INFILTRATION

Category	Average rate of infiltration, inches per hour		
	Dry soil		Wet soil
	First hour	Second hour	Third hour
I	3.5	3.0	2.0
II	2.0	1.5	0.7
III	1.5	1.0	0.3
IV	1.0	0.5	0.1
V	0.5	0.25	0.0

ical regions) and lowest for the strongly podzolized soils (podzols of northern Europe, Canada, and the USSR developed under coniferous forests). Prairie soils and the soils formed by the calcification process, chernozems, chestnut, brown, and sierozems occupy an intermediate position.

Depth to impeding stratum, which reflects the soil-forming process, parent material, and erosion, is a limiting factor under certain conditions. Claypans and hardpans on flat to gently sloping uplands and low-lying depressions with high water table are extreme examples.

The effects of a protective cover such as a dense stand of grass or of a forest with a good ground litter are: elimination of the effects of impact and sorting action of raindrops, changes in the non-capillary porosity and in some cases increase of the effective depth of the soil. The elimination of raindrop effects appears to result in doubling the rate of infiltration. Thus the effect of a dense stand of grass on a gently sloping claypan soil may be to double the inherently low initial infiltration rate; but such a cover will still not make a claypan soil comparable to a deep-sloping chernozem. Differences in runoff from protected and unprotected claypan soils are relatively small, because the amount of water that can enter the soil is limited by the shallow depth above the claypan. On the other hand, the effect of a forest or even of dense grass cover on the infiltration of deep soils or shallow soils on steep slopes can be quite pronounced, as is shown by the low amounts of surface runoff and large amounts of subsurface flow recorded on the Coweeta, Coshocton, and San Dimas experimental watersheds, on the wooded experimental watershed at Bentonville, Arkansas, and by the performance of the woods-disposal area at Seabrook, N. J.

Suggested General Values

Since it is as yet not possible to express infiltration quantitatively in terms of measurable soil properties, it is necessary to select categories of general infiltration values suitable for the solution of various problems and to assign these values to the proper combinations of soil characteristics and of other pertinent factors. Such categories must be set up with the two general uses of infiltration in mind. One requires information on the movement of water into dry soils, the other on the movement of water into and out of wet soils. The large amount of infiltration data examined by the authors, numerous records of runoff from small watersheds, of rainfall intensities and of summer rainfall patterns (2, 8, 19, 26, 30), together with due consideration of root zones and of effective depth in tractionability, indicate that the amount of water entering a dry soil in the first 60 min together with the average rates of infiltration during the second hour after the beginning of rain should prove adequate for the solution of various problems involving the movement of water into initially dry soils. Values for rates of infiltration into wet soils during the third hour after the beginning of rain are suitable for the solution of problems involving the movement of water into and through wet soils. Several soil categories with corresponding values of infiltration are suggested in Table 3. A description of soils in each of the categories follows:

Category I

(a) Gray-brown podzolic gravelly silt loams on rolling relief; developed under hardwood forests on glacial till; deep unstratified profiles interspersed with gravel; no impeding stratum.

Examples: Honeoye and Bath gravelly silt loams in south central New York and north central Pennsylvania.

(b) Red and yellow lateritic clay loams and sandy loams on undulating to rolling relief; developed in moist warm climates under coniferous and deciduous forests on volcanic tuffs and associated sandstones or on cherty limestones or on unconsolidated sand; excessively leached; deep uniform profiles with no impeding stratum.

Examples: Aiken clay loam in western Oregon and northern California, Ruston and Orangeburg sandy loams in the upper Coastal Plains of southeastern United States; red sub-tropical and tropical soils; krasnosem of the Caucasus; Clarksville gravelly loams of the Ozarks in Missouri and northwestern Arkansas.

(c) Northern leached chernozem clay and silt loams on undulating to gently rolling topography; developed under tall grasses; deep, uniformly crumbly soil with no impeding stratum.

Examples: Typical chernozem of the Tambov oblast and of the Krasnoufimsk District west of the Central Urals.

(d) Liesostep loams and light clay loams of the transition zone between hardwood forests and tall grass regions; gently rolling land; deep uniform soil with no impeding stratum.

Examples: Dark gray liesostep soils of the Orel region and of the Krasnoufimsk District west of the Urals.

(e) Deep sands, dune hills and ridges and land with deep uniform sandy soils.

Examples: Sand hills of Nebraska; sandy areas in North Dakota, South Dakota, southwestern Kansas, eastern Colorado, the Texas and Oklahoma panhandles; sandy soils of Coastal Plains with low water tables, sands of the lower Transvolga and the Pricaspian regions of the USSR, and sandy areas of the southern Chernozem Belt of the Ukraine.

Category II

(a) Chernozem friable clays and sandy clays on poorly dissected (i.e., having shallow waterways) gently sloping uplands; moderately deep, uniform profiles with impeding layer at 30 to 36 in; native vegetation of tall and short grasses.

Examples: Leached chernozem and slightly solonized chernozem of the Central Transural region Kamishlov District; Barnes loams and silt loams of South and North Dakota and western Minnesota.

(b) Prairie soils moderately deep, friable silt loams changing to somewhat more compact silty clay at about 30 to 36 in; on undulating to gently rolling upland; developed

on glacial outwash; native vegetation—tall grasses, chiefly blue stem.

Examples: Carrington silt loam of the glaciated part of the northern prairies of the United States, northeastern Iowa, parts of Illinois, Nebraska, Kansas, Minnesota, and Wisconsin.

(c) Same as *(b)* except that parent material is loess and soil is uniform to a depth of 48 in or more and transition from chernozem to Prairie on rolling relief.

Examples: Tama and Marshall silt loams of Iowa, Illinois, Missouri, and southern Wisconsin. Palouse silt loams of Washington and Idaho.

(d) Desert leached undulating to rolling clay loams and sandy loams, developed on sandstone.

Examples: Some of the soils of northwestern New Mexico and northeastern Arizona.

(e) Gray-brown podzolic deep silt loams and clay loams on limestone; developed under oak and hickory forests, on undulating to strongly rolling relief.

Examples: Hagerstown soils of the limestone valleys of Virginia, Maryland, Pennsylvania, and Tennessee.

Category III

(a) Gray-brown podzolic rolling silt loams developed on sandstone under oak forests.

Examples: Muskingum silt loam of sandstone origin in eastern Ohio, western Pennsylvania, and West Virginia.

(b) Gray-brown podzolic undulating to rolling gravelly clay loams; developed on metamorphic rock under decidious forests.

Examples: Chester-Manor soils of the northern Piedmont in Pennsylvania, New Jersey, and Maryland.

(c) Reddish chestnut undulating, moderately deep clay loam soils; developed under short grasses on deep beds of calcareous clay; impeding stratum at about 30 to 40 in.

Examples: Pullman and associated soils of the so-called "hardlands of the High Plains" of southwestern Kansas, northeastern New Mexico, southeastern Colorado, and of the Texas and Oklahoma panhandles.

Category IV

(a) Reddish chestnut steep, shallow fine sandy loams; developed under coarse grasses, such as bluestems, on "Red Beds" (clays and shales); also fine and very fine sandy loams with impeding layer at a depth of about 14 to 20 in.

Examples: Vernon fine sandy loam and Vernon very fine sandy loam in the rolling plains of Oklahoma and in north central Texas.

(b) Red and yellow podzolic undulating to gently rolling clay loams and silty clay loams; developed on slate and similar fine-textured rock under pine and hardwood forests; impeding layer of heavy sticky clay at about 7 to 10 in.

Examples: Davidson and associated clay and silty clay loam soils of the "Slate Belt" of the southern Piedmont of Georgia, South Carolina, North Carolina, and Virginia.

(c) Gray-brown podzolic undulating to rolling silt loams; developed on shale with an impeding stratum at 14 to 16 in.

Examples: Shallow, Muskingum silt loams of shale origin; Keene silt loams and associated soils of the North Appalachian region. Podzolized soils of shale origin of the Asbest district of the Transural region and other podzolized soils of the USSR.

Category V

(a) Alluvial stratified soils ranging in surface texture from sandy to clay; underlain by alternate layers of coarse and fine material.

(b) Alluvial soils in deltas of large rivers; uniform deep heavy-texture, dispersed surface soils and subsoils.

Examples: Sharkey clay of the Mississippi delta; adobe clays of Bell Fourche area and of the Red River of the North.

(c) Bog soils—peat and muck.

(d) Planosols — shallow gently sloping claypan and hardpan soils.

Examples: Putnam, Parsons silt loams and associated soils of the Clay-pan Prairies of the United States.

(e) Podzol nearly flat to flat upland shallow dispersed soil with impeding stratum at about 8 in.

Examples: Podzolic soils of the Beloiarsk district of the Transural region.

(f) All soils which occupy depressions without natural or artificial outlets and receive runoff from adjoining sloping land (with the exception of deep sands).

Examples: "Beliak" of the Kamishlov district of the Transural Region.

The average rates of infiltration presented above were derived from results of infiltration tests on cropland (cultivated or in small grains) and from runoff records from small watersheds. The values were adjusted so as to include the effect of the impact and sorting action of raindrops. The rates of infiltration in Table 3 can be used directly in the solution of problems involving bare unfrozen soil, cultivated and grain crops, and temporary or poor grass cover. For dense grass cover and for wooded land with good ground litter, the values for soils in category I can be used as given. The high infiltration rate of the soils included in this category is due to the exceptionally high stability of aggregates and of sand grains and gravel. This high stability cannot be appreciably improved by vegetative cover. For soils in categories II to V the values in Table 3 can safely be doubled. The "dry soil" values for categories IV and V apply only when the surface is not cracked; heavy-textured soils in these categories when dry and not cultivated develop wide deep cracks and take water rapidly until the soil swells.

CONCLUSION

In conclusion it will be well to repeat and underscore the following points:

1 There is good reason to believe that infiltration of unfrozen cropland, as defined in this paper, could be expressed quantitatively in terms of measurable soil properties and their variation with depth.

2 Until such time as infiltration can be expressed quantitatively in terms of soil properties that can be measured more accurately and more readily than infiltration itself,

rates of infiltration must be determined in the field whenever practicable or possible. This is particularly true in connection with the design of sprinkler irrigation systems, where determinations of infiltration, field capacity, and volume weight should and can be made. The relatively low cost of such determination is fully justified by the savings they afford in the initial cost and operation of irrigation systems.

3 General values of infiltration rates assigned on the basis of surface texture only may be so far off that they cannot be used even when general values must be resorted to.

4 The alternative scheme presented in Table 3 is believed to be rational and to correspond more closely to measured values. The soil grouping under each infiltration category and the infiltration values must be considered provisional until they have been verified in the solution of practical problems.

BIBLIOGRAPHY

1 Baver, L. D.: Soil physics. John Wiley & Sons, New York, 1940.

2 Breihan, E. R.: Relation of hourly mean rainfall to actual intensities, *Civ. Eng.* 10:303 ff. 1940.

3 Colman, E. A.: Vegetation and watershed management. Ronald Press Co., New York, 1953.

4 Cook, H. L.: The infiltration approach to the calculation of surface runoff. Trans. Amer. Geophys. Union 27, pt. 5:726-743, 1946.

5 Dolgopolova, N. N.: 1948, cited by A. A. Rode.

6 Free, G. R., Browning, G. R., and Musgrave, G. W.: Relative infiltration and related characteristics of certain soils. USDA Tech. Bul. No. 729, 1940.

7 Horner, W. W.: Role of the land during flood periods. Trans. Amer. Soc. Civ. Eng. 109: 1269-1320, 1944.

8 Horner, W. W., and Jens, S. W.: Surface runoff determination from rainfall without using coefficients. Proc. Amer. Soc. Civ. Eng. 67: 533 ff., 1941.

9 Horton, R. E.: Determination of infiltration capacity for large drainage basins. Trans. Amer. Geophys. Union 18: pt. 2, 371-385, 1937.

10 Horton, R. E.: Analyses of runoff-plat experiments with varying infiltration capacity. Trans. Amer. Geophys. Union, pt. 4, pp. 693-711, 1939.

11 Houk, I. E.: Rainfall and runoff in the Miami Valley. Miami Conservancy Dist. Tech. Rep. pt. 8, Dayton, Ohio, 1921.

12 Kachinski, N. A.: Zamerzanie, razmerzanie, etc. Trudy Nauchno-Izsledovatel'skavo Instituta Pochvovedenia, Moscow, 1927.

13 Kachinski, N. A.: in Pochvovedenie, 1945, 1947, etc.

14 Kachinski, N. A., and others: Opit agrophysicheskoi kharakteristiki pochv na primere Tzeutral'navo Urala. Moscow, 1950.

15 Kellogg, C. E.: Development and significance of the great soil groups of the United States. USDA Misc. Pub. No. 229, 1936.

16 Kostiakov, A. N.: in Pochvovedenie No. 3, 1932.

17 Kostiakov, A. N.: Ocnovi melioratzii, Moscow, 1951.

18 Krimgold, D. B.: Runoff from small drainage basins. AGRICULTURAL ENGINEERING 19:439 ff. 1938.

19 Krimgold, D. B.: A suggested method of reporting rainfall records. Trans. Amer. Geophys. Union pt. 6, pp. 835-837, 1944.

20 Krimgold, D. B.: On the hydrology of culverts. Proc. 26th Annual Meet. Highway Research Board, 1946.

21 Krimgold, D. B.: Economic feasibility of supplemental irrigation. AGRICULTURAL ENGINEERING 35 : 22-27, 1954.

22 Krimgold, D. B., Weber, J. L., and Minshall, N. E.: Some preliminary results from run-off studies on demonstration projects. *Soil Cons.* pp. 186-190, 1940.

23 Lewis, M. R.: The rate of infiltration of water in irrigation practice. Trans. Amer. Geophys. Union, pt. 2, pp. 361-368, 1937.

24 Mamanina, L. F.: Vodopronitzaiemost' pochv tzentral'nochernosemnoi polosi, Oroshenie sel'skokhosiaistvenikh kul'tur v tzentral'noi polisa. R.S.F.S.R. sbornik rabot vol. 1, Akad. Nauk S.S.S.R., Moscow, 1952.

25 Marbut, C. F.: Soils of the United States. Part 3 of Atlas of American Agriculture, U.S. Gov. Print. Off., 1935.

26 Minshall, N. E.: Effect of conservation practices on watershed yields (manuscript 1951).

27 Musgrave, G. W., and Augustine, M. W.: Infiltration measurement on plots of the Division of Dry Land Agriculture at Fort Hays (Kansas) Experiment Station (manuscript 1944).

28 Musgrave, G. W.: The infiltration capacity of soils in relation to surface runoff and erosion. *Journ. Amer. Soc. of Agronomy* 27 : 335-345, 1935.

29 Rode, A. A.: Pochvenaia vlaga. Moscow, 1952.

30 Schiff, L.: Classes and pattern of rainfall with reference to surface runoff. Trans. Amer. Geophys. Union, pt. 2, pp. 438-451, 1943.

31 Sherman, L. K., and Musgrave, G. W.: Infiltration, in Hydrology, ed. by O. E. Meinzer, Dover Publications, Inc., New York, 1949.

32 Soils and men, USDA Yearbook of Agriculture, 1938.

Draintile Durability

(Continued from page 718)

The packer cheeks are designed to extend 1/32 to 1/16 in outside the packer ring. They compact and trowel the inside of the tile as the head assembly revolves as it passes vertically through the tile.

Adequate Curing

All concrete draintile should be moist-cured in accordance with good practices so that previous to installation they will meet the ASTM strength and absorption requirements.

Satisfactory methods for the moist-curing of concrete tile are of two distinct types: *(a)* water spray or fog at the temperatures which prevail and *(b)* saturated steam at temperatures which may be anywhere between 100 and 190 F.

Moist curing of the spray type when continued long enough during favorable weather is adequate, but oftentimes is impractical when the demand for tile is such that the tile must be delivered before they have had an opportunity to cure 28 days. When saturated steam is properly used, the curing period can be shortened to a few days. From the Minnesota work it appears that a temperature of 155 F, plus or minus 15 deg, is as high as necessary in a curing room when draintile are cured with saturated steam, strength alone considered. For best results, the curing operations will require the greater part of two days.

Conclusions

While there may be differences of opinion regarding the details of nearly all the procedures outlined, perhaps the greatest divergence of thought will be in connection with aggregate gradation and with curing practices in relation to effectiveness at early ages. In particular the effects of different proportions of the finer aggregate particles on both strength and absorption of draintile is a disputed matter. Studies based on additional data are planned to clarify both of these phases of concrete draintile manufacture.

BIBLIOGRAPHY

1 Long-time performance of some clay draintile. AGRICULTURAL ENGINEERING, vol. 32. February, 1951.

2 Durability of concretes and mortars in acid soils with particular reference to draintile. Technical Bulletin 180, University of Minnesota Agricultural Experiment Station. June, 1948.

3 Long-time tests of concretes and mortars exposed to sulfate waters. Technical Bulletin 194, University of Minnesota Agricultural Experiment Station. May, 1951.

4 Making durable concrete draintile on packer-head machines. Bulletin 426, University of Minnesota Agricultural Experiment Station, May, 1954.

Drain-Spacing Formula

Lee D. Dumm

New Formula for Determining Depth and Spacing of Subsurface Drains in Irrigated Lands

PRACTICALLY every area, where irrigation has been carried on for any length of time, has land that has become waterlogged or salted or lands on which crop production has been affected by high water tables. Therefore, the provision of adequate drainage is an essential part of the planning, construction, and operation of an irrigation development.

Drainage problems in humid areas are usually evident from visual inspection of an area, since they are the result of natural conditions which have prevailed for many years. This is not true, however, of a proposed irrigation development. Here the drainage problems are generally the result of man-made conditions brought about by irrigation and may not be apparent until several years after the start of irrigation.

The Bureau of Reclamation in planning new irrigation developments and determining the feasibility of projects is required to forecast or predict the extent of future drainage problems in areas where none now exist. And, since the feasibility of a project depends upon the benefits derived versus the costs involved, it is essential that the cost estimates be sufficiently adequate to include ultimately required drainage facilities.

Most irrigated areas developed in the past have had favorable natural substrata drainage characteristics which did not require the use of closely spaced drains to control high water tables. In general, most of these have been in arid lands underlain by sand or gravel strata into which excess water can percolate vertically and then move laterally through the permeable sand or gravel to natural outlets or constructed drains. Over the years a vast amount of experience has been gained in determining drainage requirements of such lands.

Since the better lands have been developed, however, we now find that many proposed developments do not have these favorable natural drainage characteristics, and therefore closely spaced drains are usually required. Experience in subsurface drainage of such lands is rather meager. This lack of experience has led to the development of various drain-spacing formulas to meet the needs of planning and developing such areas.

The typical profile often encountered and for which the formulas have been developed is one in which a relatively permeable soil overlies a very slowly permeable strata or one in which the profile becomes less permeable with depth. Under these conditions relatively close spacing of drains is required, since the excess water must be moved laterally through the profile to the drains.

Drain-spacing formulas to date have been developed on the basis of steady-state flow conditions, which do not entirely satisfy the conditions of irrigation. Other formulas have been developed to meet the requirements of a particular area.

The Bureau of Reclamation is planning, developing, and operating many irrigation projects in the western states. These projects embrace a wide diversity of soils and ground-water conditions. The need for a drain-spacing formula which would be applicable to these widely varying soil and ground-water conditions has become increasingly evident. Such a formula should include as many factors pertaining to irrigation drainage as possible. To meet this need, R. E. Glover, engineer of the Bureau, has developed a theoretical mathematical formula which we feel incorporates most of these factors.

Our purpose in presenting the formula is to point out the factors which we think have a bearing on irrigation drainage and to explain the methods we have used in developing the formula. Although we have not yet been able to conduct extensive laboratory experiments and field trials to verify the use of the formula, we find it more compatible with our experience over a variety of conditions than any other. Until we can further substantiate the results, we would welcome comments or research checks from anyone interested in drainage.

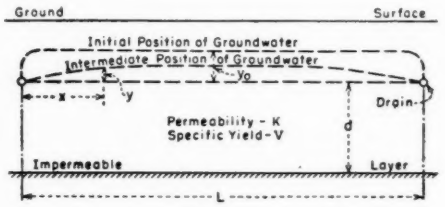


Fig. 1

The development and use of the formula are predicated upon the following conditions and assumptions:

1 Normal irrigations at regular intervals.

2 Uniform or stratified soils overlying a slowly permeable stratum or barrier layer.

3 Permeability of the profile equal to the weighted average permeability of the soil or soils above the barrier layer.

4 The drainage requirement, or excess water to be disposed of, is the difference between the net input of water and the available moisture storage in that portion of the profile which must be kept clear of gravity or noncapillary water in order to provide for root growth and salinity control.

5 Excess water must be removed between irrigations in order to maintain the water table below the root zone. This would require that sufficient storage space for gravity water be provided below the root zone for the inflow of excess water from the following irrigation.

6 Water moving through the soils is in a transitory state rather than a steady state, i.e., the head available to push the water toward the drains varies with time.

Paper presented at the annual meeting of the American Society of Agricultural Engineers at Minneapolis, Minn., June, 1954, on a program arranged by the Soil and Water Division.

The author—LEE D. DUMM—is engineer, drainage and ground-water engineering office, design and construction division, Bureau of Reclamation, U.S. Department of the Interior.

7 Movement of water through a soil is proportional to the ground-water gradient and to the depth of saturated thickness between the water table and the slowly permeable layer or barrier.

Many of the results obtained from the theory of heat conduction in solids also apply to the movement of water through soils. Let us first assume a condition represented by Fig. 1.

In this case, an increment of ground water of an initial uniform drainable depth y_o flows toward horizontal drains spaced at a distance L apart. The aquifer, of permeability K, extends below the level of the drains to a depth d. If y represents the depth of the ground water above the elevation of the drains at some horizontal distance x measured from one line of the drains toward the other, as shown on Fig. 1, then the condition of continuity is, approximately, if y_o is small compared to d,

$$\frac{\partial y}{\partial t} = \frac{KD_a}{V}\frac{\partial^2 y}{\partial x^2} \quad \ldots\ldots\ldots [1]$$

Where $D_a = d + y_o/2$ represents an average thickness of aquifer available for carrying water to the drains, a solution of this equation subject to the conditions,

$y=0$ when $x=0$
$y=0$ when $x=L$
$y=y_o$ when $t=0$ for $0 < x < L$,

and with $\alpha = KD_a/V$ is

$$y = y_o \frac{4}{\pi} \sum_{n=1,3,5,\text{etc.}}^{n=\infty} \frac{e}{n}^{-\frac{\alpha n^2 \pi^2 t}{L^2}} \operatorname{Sin} \frac{n\pi}{L} x \quad \ldots [2]$$

A simplified formula useful for estimating drain spacings may be obtained from the above expression on the following basis: The most difficult point to drain is the point midway between the drains, or the point at which $x = L/2$. For this value of x the sine terms take on the successive values of $+1$ and -1. After the lapse of sufficient time the water level midway between the drains begins to lower, and at about this time all the terms in the series, except the first term, have also become quite small. When the parameter $\alpha\, t/L^2$ reaches 0.025, for example, the first term has the value 0.7788, while the second term has the value -0.0362. Then we can say that, for significant amounts of lowering of the water table at $x = L/2$, we can consider the first term only and, to a sufficient approximation

$$y_c = y_o \frac{4}{\pi} e^{-\frac{\alpha \pi^2 t}{L^2}} \quad \ldots\ldots [3]$$

We can write this relation in the form

$$\log_e \frac{\pi y_c}{4 y_o} = -\frac{\alpha \pi^2 t}{L^2} \quad \ldots\ldots [4]$$

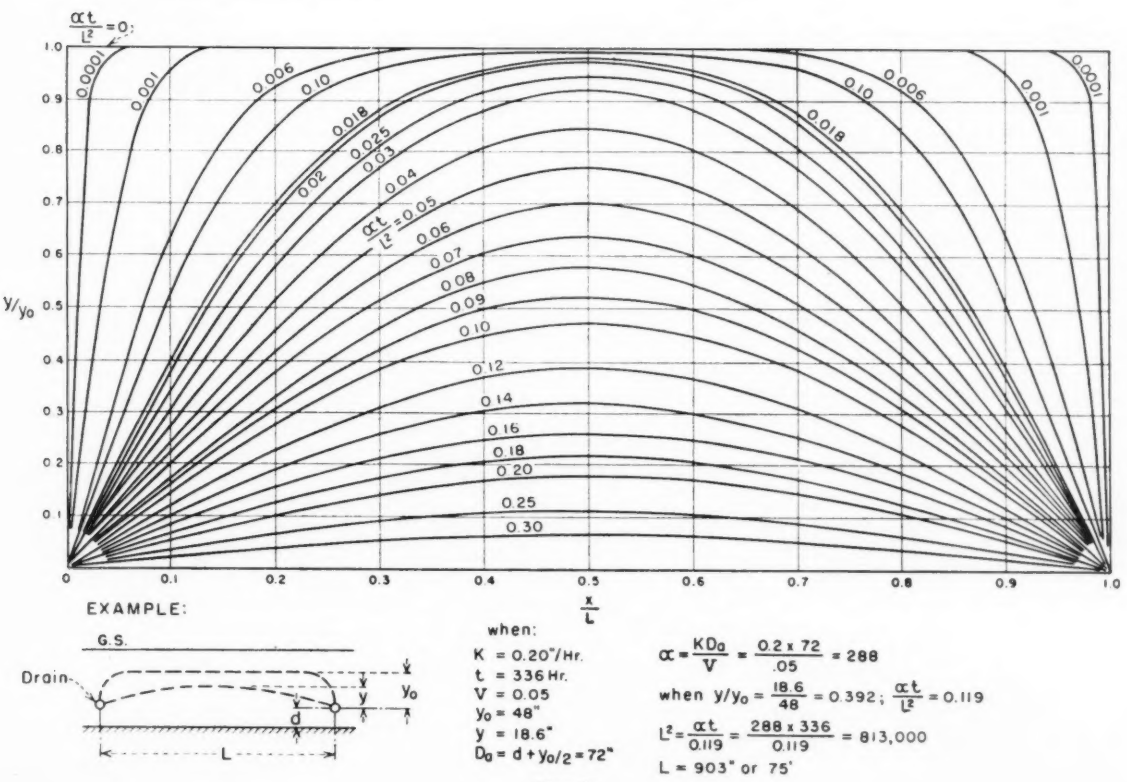


Fig. 2

The drain-spacing formula obtained by solving this expression for L, when $\alpha = K D_a/V$ is,

$$L = \pi \sqrt{\frac{K D_a t}{V \log_e\left(\frac{4}{\pi}\frac{y_o}{y_c}\right)}} \quad . \quad . \quad . \quad . \quad . \quad [5]$$

where L=spacing, in inches

K=permeability, in inches per hour

t=time between irrigations, in hours

V=specific yield of the soil

y_o=distance between tile and maximum allowable ground water, in inches

y_c=distance between tile and water table at $x=L/2$ at end of period between irrigations, in inches

d=distance between tile and impermeable layer, in inches

D_a=average depth of drainable section, or $d+y_o/2$, in inches

The successive ground-water profiles, as given by equation [2] are shown in Fig. 2. By use of this chart the pattern of movement of water to the drains may be traced. The drain spacing required to remove ground water to a specified depth may also be found by use of the chart by finding the value of $\alpha\ t/L^2$ required to produce the necessary lowering and solving this relation for L.

Although the above formulas are derived under the assumption that y_o is small compared to d we shall see later that, if we use $D_a = d + (y_o/2)$ as the effective thickness of the aquifer, they do give a fairly satisfactory approximation even though the drains are placed at the bottom of the aquifer.

We next give consideration to a case where the drains are placed at the bottom of the aquifer and in which we take account of the saturated thickness of the aquifer explicitly. This development provides a means of comparison for the extreme case and permits an evaluation of the error introduced by using the methods outlined above when y_o is not small compared to d.

Let us assume a ground-water profile, terminating at drains spaced at distance L apart at the bottom of the aquifer, of permeability K, and an initial saturated depth H at a point midway between the drains. If Z represents the saturated thickness of the aquifer at the distance x, measured horizontally from one line of drains, as shown on Fig. 3, then the condition of continuity is

$$\frac{\partial}{\partial x}\left(KZ\frac{\partial Z}{\partial x}\right) = V\frac{\partial Z}{\partial t} \quad . \quad . \quad . \quad . \quad . \quad [6]$$

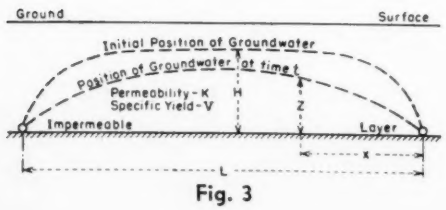


Fig. 3

A solution of this equation is

$$Z/H = WY \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [7]$$

where W is determined from the relation

$$\int_0^W \frac{W\,dW}{\sqrt{1-W^3}} = \sqrt{3}\,\frac{x}{L} \quad . \quad . \quad . \quad . \quad . \quad [8]$$

and Y is given by

$$Y = \frac{1}{\frac{9}{2}\left(\frac{\alpha t}{L^2}\right)+1}$$

with $\alpha = KH/V$

If Z_c represents the value of Z at $x=L/2$ at the time t, then, since $Y=Z_c/H$, a rearrangement of the expression for Y yields

$$t = \frac{2L^2}{9\alpha}\left(\frac{H}{Z_c}-1\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [9]$$

If this expression is solved for L, we get a formula for the drain spacing which is

$$L = \sqrt{\frac{9KHt}{2V\left(\frac{H}{Z_c}-1\right)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [10]$$

The ground-water surface profiles implied by this solution are shown on Fig. 4. It will be noted that a uniform depth of ground water is not assumed to exist at time zero, as in the first case. The substitution of a reasonable initial profile is done as a concession to the mathematical difficulties since the non-linear differential equation that applies to this case is very difficult to solve when a uniform initial distribution is assumed. It is believed that no appreciable error is introduced by making this concession.

With these two cases we now possess treatments of drainage rates where the drains are placed at shallow depths in the aquifer and where the drains are placed at the bottom of the aquifer. The intermediate case remains without adequate treatment, and we will, therefore, try to provide this by making a choice of D_a so that the first case may be used for drain placement near the middle of the aquifer also. We will make the choice of D_a by comparing a linear and a non-linear steady-state case. In these cases we will assume that the water flowing to the drains is provided by a steady infiltration, i. In the steady-state case the continuity condition will take the form

$$KD_a\frac{d^2y}{dx^2} = -i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad [11]$$

and the solution, subject to the requirements that

$y=0$ when $x=0$

$y=0$ when $x=L$

is $$y = \frac{i}{2KD_a}(Lx - x^2) \quad \ldots\ldots\ldots \quad [12]$$

For the non-linear case the continuity condition is

$$\frac{d}{dx}\left(KZ\frac{dz}{dx}\right) = -i \quad \ldots\ldots\ldots \quad [13]$$

And its solution subject to the requirements

$Z=d$ when $x=0$

$Z=d$ when $x=L$

is $$\frac{z^2}{2} - \frac{d^2}{2} = \frac{i}{2K}(Lx - x^2). \quad \ldots\ldots\ldots \quad [14]$$

If the infiltration i is the same in both cases and we make $Y=H-d$ and $Z=H$ at $X=L/2$, then by comparison of equations 12 and 14 we can write

$$D_a(H-d) = 1/2\,(H^2-d^2)$$

from which we obtain

$$D_a = (H+d)/2$$

In the notation used with the original case this is equivalent to

$$D_a = d + y_o/2$$

This result indicates that our best choice of D_a is obtained as the arithmetic mean of H and d. A comparison of the first case with this value of D_a with the second case, on the basis of the drain spacing required for a moderate lowering of the water table, will show that the first case provides a reasonably accurate treatment of the extreme case where the drains are placed at the bottom of the aquifer. Fig. 5 shows that the use of this value of D_a in formula [5] for the first case gives values within 10 percent of those obtained for the extreme case by the use of formula [10]. We may conclude, therefore, that the intermediate case can be solved approximately by this method also.

The use of the above value of D_a succeeds in removing the restrictions on the use of the first case for the intermediate drain placement, but it does not remove restrictions of another sort. It still remains essential to restrict the use of the first case to those situations where the amount of lowering of the water table is moderate. It will be readily apparent that if we were to try to estimate the time required to drain away, say three-fourth of the original saturated depth that the initially chosen value of D_a would become inappropriate to represent the saturated thickness of the aquifer which would prevail toward the end of the drainage period. It is thought that in actual practice lowering of the water table by moderate amounts will be the rule, but if for any reason it should be desirable to apply the first case to situations having relatively large amounts of drawdown, it is suggested that the computation be made in steps with a new value of D_a selected for each step. Restrictions on the amount of drawdown are not necessary when using the second case.

The local resistance to the flow of water as it converges toward the drain has been neglected in these developments.

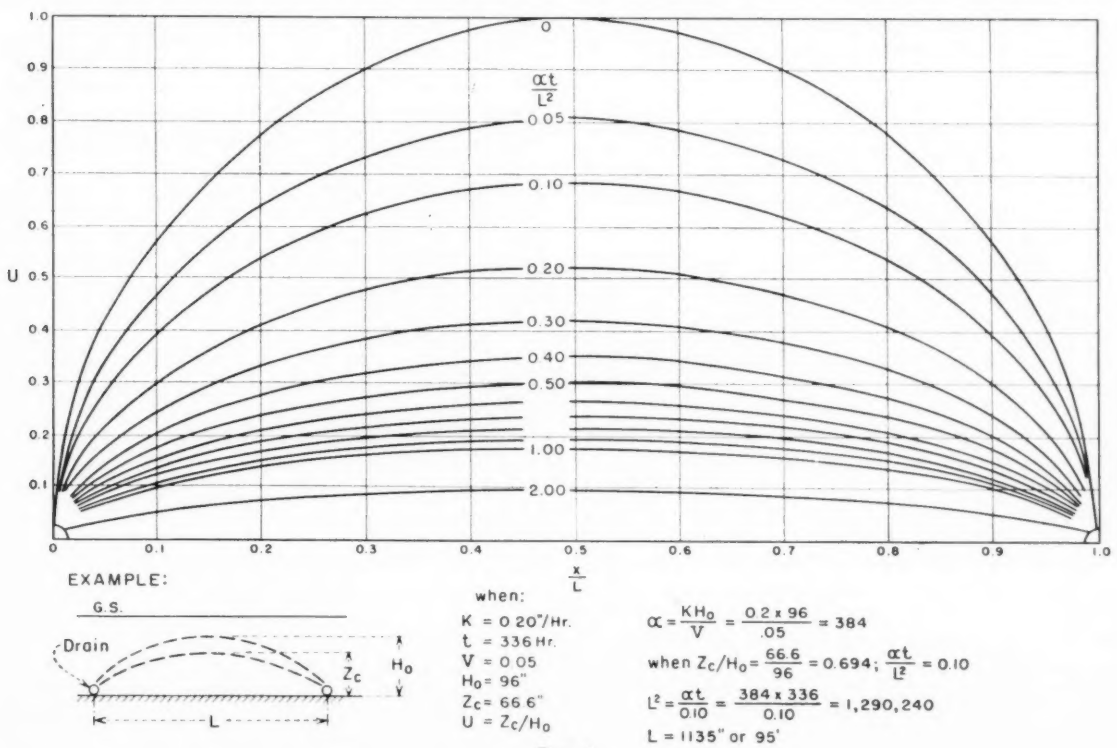


Fig. 4

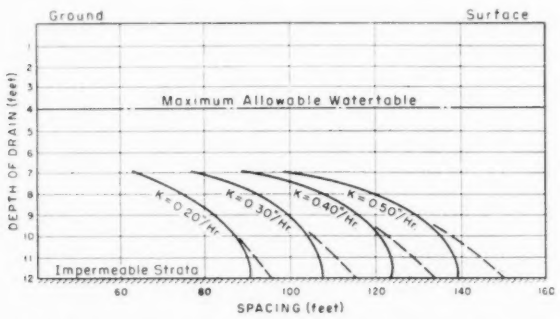


Fig. 5 Comparison of the drain-spacing formula [5] using the value of $Da=d+y_o/2$ for the extreme case where the drain is placed at the impermeable strata (shown by solid lines) versus the use of formula [10] (shown by dashed lines). (NOTE: Curves computed for same conditions, except for drain depths and permeabilities, as outlined in the accompanying example)

This convergence can be accounted for only by considerable complications of the formulas. Comparisons of drain spacings determined with and without this refinement show only a slightly shorter spacing when local resistance is included. The basic inaccuracies of much of the data involved in the use of the formulas do not, from a practical standpoint, appear to warrant this refinement.

An example of the use of the formula is given in the following paragraphs.

Assume a clay-loam soil with a permeability of 0.2 in per hr; a water-holding capacity of 2.15-in per ft at wilting point and 3.46 in per ft at field capacity; and a specific yield of 5 percent. Twelve feet of this material overlies a very slowly permeable stratum. Assume a 6-in irrigation application every 14 days, a 10 percent surface loss, and a maximum allowable water table of 4 ft below the ground surface. The problem is to determine the spacing of drains when the tile line is placed at 8-ft depth.

If a 10 percent surface loss occurs, only 90 percent, or 5.4 in of water, actually goes into the soil. If the top 4 ft of the soil profile is to be kept free of gravity water, then this

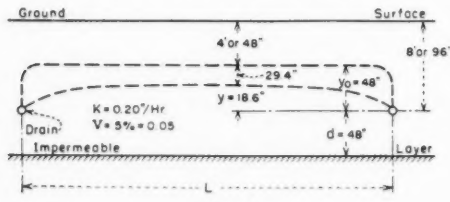


Fig. 6

4-ft column of soil will store only that amount of water used by the plants from this column between irrigations. Research information indicates that during a normal irrigation period of about 14 days the consumptive use of the plants is approximately the difference between field capacity and wilting point in the top 2 ft of the soil profile. In the next 2 ft the consumptive use is approximately one-half this difference. Therefore, the amount of capillary water that can be stored from the 6-in irrigation in the top 4 ft is $2(3.46-2.15)+2(3.46-2.15)/2=3.93$ in. The remaining amount of water, $5.4-3.93=1.47$ in, entering the soil must, therefore, be temporarily stored below the 4-ft zone and drained out before the next irrigation if the water table is not allowed to rise above 4 ft below the ground surface. Since the specific yield of the soil is 5 percent, it will take $1.47\times 20=29.4$ in of soil to store the drainage requirement of 1.47 in.

Fig. 6 illustrates the conditions under this assumption.

Then substituting the foregoing figures in formula [5],

$$L=\pi\sqrt{\frac{0.2\times 72\times 336}{0.05\log_e\left(1.27\times\frac{48}{18.6}\right)}}=\pi\sqrt{\frac{4838.4}{0.05\times 1.18}}$$

$L=905$ in, or approximately 75 ft.

Checking with Fig. 2,

$$\alpha=KD_a/V=(0.2\times 72)/0.05=288$$

when $y/y_o=18.6/48=0.388$; $\alpha\, t/L^2=0.119$,

then $L^2=\alpha\, t/0.119=(288\times 336)/0.119=813{,}000$

$L=903$ in, or approximately 75 ft.

If in the above example we had assumed a 4.8-in irrigation application, we would have a drainage requirement of 10 percent of the net input. Using this value as the amount of water to be removed, and with all other conditions the same, we would find that the formula gives a drain spacing of 126 ft rather than the 75 ft in the example. It can be seen, therefore, that the amount of water to be removed by the drains is an important consideration in the use of the formula.

It might be asked, at this point, why we do not apply only enough irrigation water to provide the plants with their actual requirements and thereby do away with the necessity of providing drains to dispose of excess ground water. There are several answers to this, such as the requirement of a certain amount of deep percolation for salinity control, the physical impossibility of attaining 100 percent efficiency in irrigation, and the practical limits imposed by the managerial ability and equipment of the average irrigator.

In concluson, it should be kept in mind that, while a proper mathematical equation may be written to satisfy the conditions set up for a particular problem, it is practically impossible to satisfy completely these conditions on an area basis, even if all of the factors involved could be measured with any great degree of accuracy. Permeabilities can be measured only in relative terms, soils are usually very nonuniform even over small areas, forecasts of irrigation practices can only be relative, and the amount of natural drainage that will occur is usually indefinite or unknown. Therefore, any answer derived from a mathematical spacing formula must be used with proper judgment and should be checked with results obtained from experience before it is given widespread use as a basis of construction layout.

We find it necessary, however, to develop a reasonable estimate of future drainage requirements and costs for areas with the conditions described in order to determine feasibility of projects and to provide sufficient funds to meet the drainage problems when they arise. For these reasons we use drain-spacing formulas primarily as a means of predicting the approximate depth and spacing in areas where experience is lacking. We feel that the formula, when used with judgment, is satisfactory for this purpose

Some Effects of Mulch Tillage

F. W. Schaller and D. D. Evans

Report on Studies of Factors Possibly Responsible for Yield Reduction

CROP residue used as mulch promises to be an increasingly important method for achieving greater soil and water conservation on cultivated land. Many studies (23)* during the past 20 years have demonstrated the effectiveness of mulch in controlling erosion and conserving soil moisture. However, mulch tillage has not gained wide acceptance by farmers, particularly in the corn belt and eastern United States. An important reason for the lack of acceptance is that corn yields are frequently lower under mulch tillage than with conventional plowing. The purpose of this paper is to present a review of pertinent literature and to report recent data from Iowa studies concerning some of the factors in mulch tillage possibly responsible for yield reduction.

Literature Review

Studies have been reported which show that mulched soil, in contrast to bare soil, tends to produce a better granular structure at the soil surface. Duley and Russel (9) have presented photographs which show that soil mulched with 4 tons per acre of straw developed a much better granular structure one year after application than soil identically treated but without mulch. Stephenson and Schuster (24) measured soil aggregation at the end of the third year for mulched and bare plots, and found the mulched plots to have the more stable structure.

Applications of mulch to the soil surface increases the moisture content of the soil. Many investigators (3, 8, 9, 10, 24, 27) have found this to be true. The increase in moisture content under a mulch may be attributed to a greater infiltration rate and lower evaporation rate.

Another factor affected by mulch is soil temperature. McCalla and Duley (16) concluded from their experiments that soil temperatures can be reduced considerably by applications of large amounts of crop residues to the soil surface. Also, they concluded that when just the residue from the preceding crop is allowed to remain on the surface, the temperature may be reduced some but not enough to influence growth of plants. Verma and Kohnke (27) measured temperatures that were consistently lower on plots receiving 3,000 lb of wheat straw, corn stover, or glass wool than on bare plots. Data presented by Englehorn (11) show the same thing. The temperature differential is explained by the greater reflection of radiant energy by the mulch than the soil surface, the insulation effect of the mulch, and the greater specific heat of the soil under a mulch due to the higher moisture content.

There have been some measurements of soil physical properties of soil where plowing and subsurface tillage have been compared. Page *et al.* (20) showed that at the end of the first growing season both the total porosity and the air porosity are lower for subsurface tilled plots compared to plowed plots. Their results also showed that subsurface tilled soil was less penetrable than plowed soil.

It has long been known (1, 2, 17, 19, 22) that soil nitrates are reduced by surface applications of carbonaceous residues. Such reductions often result in lowered crop yields.

Tillage methods may influence uptake of nutrients by plants. With corn plants, the ability to take up nutrients from the soil and its relation to yield can be effectively evaluated by analysis of leaves or whole plants (4, 26). Such analyses were used by Bower *et al.* (5), in Iowa, in making a comparative study of the effects of seedbed preparation methods on N and K deficiency of corn. The study showed that on Tama soil there was little evidence of N deficiency in corn on plowed soil, whereas on disked or subsurface-tilled soil nitrogen deficiency was quite marked. Tillage had no apparent effect on the P and K content of the plants. Fertilizer was effective in increasing yield from all tillage methods except plowing where nitrogen apparently was not deficient.

In the same study by Bower *et al.*, but on Fayette, Webster and Clarion soils, it was found that the K content of corn plants on plowed soil was considerably higher than that on disked or subsurface tilled soil. Plant deficiency symptoms and lower corn yields resulted from the potash deficiency in the latter two tillage methods. The authors suggest that a difference in soil aeration as a result of tillage may have been responsible for the difference in uptake of K. It has been well established by other workers (14, 21) that K absorption by plant roots is dependent on oxygen supply.

Moody *et al.* (19) analyzed corn plants over a 3-year period, 1948 to 1950, and compared results from conventional plowing with mulch tillage using a double-cut plow. They found that the percentage of nitrogen in corn plants was significantly higher in the conventional tilled plots in two of the three years. Phosphorus content of corn plants was not affected by tillage. The potassium content of plants from mulch-tilled plots was significantly lower in one of the three years. The amount of crop residue on the soil surface combined with that in the top 3 in of soil was suggested as the important factor affecting reduced availability of nitrogen. Applications of nitrogen fertilizer (up to 95 lb per acre of N) increased the nitrogen content of corn plants. However, in high yield years, fertilizer failed to bring the nitrogen content of mulch-tilled corn up to the level of that on plowed soil.

Placement of crop residues on or near the soil surface has an important effect on distribution and activity of soil organisms. Dawson *et al.* (7) studied the effect of plowing and subtilling on distribution of microorganisms

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1953, on a program arranged by the Soil and Water Division. Approved as Journal Paper No. 2555 of the Iowa Agricultural Experiment Station, Ames, Project 787. Joint contribution of the agronomy department, Iowa State College, and the soil and water conservation research branch (ARS), U.S. Department of Agriculture.

The authors—F. W. SCHALLER and D. D. EVANS—respectively, associate professor of soils, Iowa State College, and soil conservationist, U.S. Department of Agriculture, and assistant professor of soils, Iowa State College. (The senior author is now extension agronomist, Iowa State College, and the junior author is associate professor of soils, Oregon State College.)

*Numbers in parentheses refer to the appended bibliography.

in the 0- to 1-in and 1- to 6-in soil layer. Results showed that the top inch of soil frequently contained greater numbers of microorganisms under subsurface tillage, while the 1- to 6-in layer contained greater numbers where residues were plowed under. This type of distribution occurred with both grain straw and sweet clover residues. The stimulatory effect caused by the crop residues was greatest during the early stages of decomposition and largely disappeared after about nine months.

Gamble *et al.* (12) studied the influence of double-cut plow mulch tillage on number and activity of microorganisms and found a significantly higher mold count under mulch tillage. They suggest that this group of microorganisms might cause a temporary loss of nitrate-nitrogen.

TABLE 1. YIELDS OF CORN GROWN WITH DIFFERENT TILLAGE METHODS ON WEBSTER SILTY CLAY LOAM IN 1952*

Tillage method	Corn yield per acre, bu	
	No fertilizer	With fertilizer
Conventional plowing	68.1	85.7
Plowed - residue removed	65.4	84.8
Plowed - residue on surface	51.7	65.9
Subsurface-tilled	54.1	56.3

*Fertilizer per acre: 400 lb 4-16-0 applied in the row, 160 lb 0-0-50 broadcast, and 240 lb 33-0-0 side-dressed. Differences in corn yields due to fertilizer and tillage were significant at the 1 percent level.

Several studies by McCalla *et al.* (15, 16, 17, 18) have emphasized the effects of crop residues and mulch on the activity of soil microorganisms. Under some conditions the effects have been stimulatory and under others the reverse has been true.

The work of Broadbent (6), as well as many others, has shown that decomposition of highly carbonaceous residues such as grain straw and cornstalks can tie up large quantities of soil nitrogen. Decomposition of such residues under mulch tillage may be especially detrimental to corn plants because of their root distribution and feeding area. This is suggested by the work of Hall (13), who has shown that for a corn plant the 3-in soil horizon makes a very high nutrient contribution during the first five weeks. By the end of seven weeks this horizon has contributed approximately 40 percent to the total growth. Thus, it is evident that growth of young corn plants could be seriously hampered by tie-up of plant nutrients, especially nitrogen, resulting from decomposition of crop residues on the soil surface and in the top 3 in of soil.

Recent Studies in Iowa

Much tillage studies in Iowa in 1952 and 1953 have been directed toward a determination of the effects of crop residue placement on microbiological activity and nutrient availability. The study is still in a preliminary stage, and pertinent results will be presented here as a progress report.

In both years of study four methods of seedbed preparation for corn were compared, as follows: *(a)* conventional plowing, *(b)* plowed with residue removed, *(c)* plowed with residue removed before plowing and returned to the soil surface after plowing, and *(d)* subsurface tillage using 24-in Dempster sweeps with tillage at about 3 in deep followed by a second operation at about 7 in deep. In 1952 the tillage treatments were compared with and without fertlizer, and in 1953 different rates of nitrogen were used with each tillage method. The plots were randomized and replicated four times. They were located on cornstalk land and consequently the mulch residue was from the previous corn crop. The cornstalk residue averaged 2 to 2½ tons per acre. All seedbeds were prepared in May a few days before corn planting.

Results in 1952

The 1952 experiment was located at Ankeny, Iowa, on a Webster silty clay loam soil. The treatments used and the corn yields obtained in the study are presented in Table 1. Results show that higher corn yields were obtained where the cornstalk residue was removed or plowed under than where it was located on the soil surface. Leaving crop residues on the soil surface reduced yields an average of 21 percent on unfertilized plots and 28 percent on fertilized plots. All plots showed nitrogen deficiency symptoms by silking time, but it was more pronounced on plots with surface residue. Weeds were plentiful in all plots, but tended to be higher on subsurface tilled plots. The high weed population undoubtedly competed vigorously for available nitrogen. There was some variation in corn stands, but no significant differences due to tillage or fertilizer.

Microbial numbers, mainly bacteria and actinomycetes, were determined on all unfertilized plots in 1952. Determinations were made for two soil horizons, 0 to 3 and 4 to 7 in, on five different dates. A dilution plate-count method was used.

TABLE 2. EFFECT OF TILLAGE METHODS ON MICROBIAL NUMBERS IN WEBSTER SILTY CLAY LOAM IN 1952

Date of sampling	Soil horizon, in	Microbial numbers (millions per gram of soil)			
		Conventional plowed	Plowed residue removed	Plowed residue on surface	Subsurface tilled
May 26-29*	0-3	208	179	222	219
	4-7	216	200	168	199
June 10-12*	0-3	133	130	187	192
	4-7	162	150	154	166
June 26-30	0-3	110	106	120	124
	4-7	101	106	99	104
July 16	0-3	109	98	107	104
	4-7	105	98	94	93
August 5-6*	0-3	61	66	63	77
	4-7	72	63	60	55

*Differences between tillage methods are significant at the 5 percent level.

Microbial counts are presented in Table 2. Inspection of the data shows that microbial populations were high and that tillage treatments affected the profile distribution of organisms in the soil. On statistical analysis, significance between treatments was encountered at the 5 percent level on three of the sampling dates, May 26-29, June 10-12 and August 5-6. On these dates, microbial numbers in the 0- to 3-in soil horizon with residues on the soil surface were higher by 13.9 percent, 44.3 percent, and 11.1 percent, respectively, than where no residues were present on the soil surface. In the 4- to 7-in soil horizon the reverse relationship was found in May and August and essentially no differences in June. Here microbial numbers in plots without

surface residue were higher by 13.7 percent on May 26-29 and 17.5 percent on August 5-6.

The microbial distribution would indicate that very favorable conditions were present for microbial activity under mulch tillage. This would be expected since some of the mulch becomes mixed with the surface soil during tillage and planting operations. Rainfall was plentiful during May and June, and moisture was adequate. The high microbial counts would indicate that temperature and oxygen supply were favorable.

TABLE 3. EFFECT OF TILLAGE METHODS ON PERCENTAGE OF NITROGEN, PHOSPHORUS, AND POTASSIUM IN CORN LEAVES ON WEBSTER SILTY CLAY LOAM, 1952*

Tillage method	No fertilizer N	P	K	With fertilizer N	P	K
Conventional plowing	2.06	0.23	1.48	2.18	0.21	1.60
Plowed - residue removed	1.96	0.24	1.43	2.14	0.21	1.59
Plowed - residue on surface	1.85	0.27	1.47	1.74	0.22	1.60
Subsurface tilled	1.65	0.23	1.36	1.66	0.20	1.41

*See Table 1 for fertilizer treatment. Differences in N content caused by tillage were significant at the 5 percent level.

The microbiological study as such provides no basis for interpreting the significance of the yield data. However, as shown (Tables 1 and 2), corn yields were reduced on plots with surface residue and where microbial populations were highest in the 0- to 3-in horizon. This suggests that perhaps microbial activity is secondary to aeration and other factors that directly affect crop yields, or that microbial response as it affects nitrification or other soil processes is a factor directly influencing yield of corn.

Soil-moisture samples were collected and the moisture content determined by direct weighings at five different dates from May to August. The moisture content between 0 to 3 in and 4 to 7 in was determined for each tillage treatment. A statistical analysis of the data shows no difference among treatments, so the data will not be presented.

Soil temperatures were measured at four dates at two depths, 1½ in and 5½ in. On May 5, which was prior to any soil tilling, temperature measurements were made on soil covered with about 1 in of mulch and on bare soil occurring on the same plots. Temperature under the mulch was 10.3 and 4.9 F cooler than the bare soil at the 1½- and 5½-in depths, respectively. Average measurements at other dates on all plots showed very little difference in temperature. The maximum difference occurred on June 11 at 4:00 p.m. when plowed plots with residues placed back on the surface were 5.5 degrees cooler in the surface layer than plowed plots without residue. At no time was there a difference measured between the plowed plots and the subsurface tilled plots.

Soil structural measurements were made on 3-in core samples from all plots taken between July 18 and 22. The following determinations were made on the samples: moisture at sampling time, total porosity, pores drained by 50 cm of water tension, pores not drained by 50 cm of water tension, and pores occupied by air at sampling time. The only statistical significant difference measured was the pores drained by 50 cm of water tension. The average percentages of pores drained were 6.1, 5.6, 5.8 and 7.3 for the treatments conventionally plowed, plowed with residues removed, plowed with residues removed and then replaced on surface, and subsurface tilled, respectively.

Corn leaf samples were collected at silking time from each plot in the 1952 experiment. The leaf opposite and just below the ear was selected for the sample. Analysis for nitrogen, phosphorus and potassium were made and the results are presented in Table 3. These data show that in all treatments with or without fertilizer the content of nitrogen in corn leaves was too low for best corn yields. However, leaf nitrogen tended to be lower in corn grown under tillage methods which left crop residues on the soil surface than where residues were removed or plowed under. There was no significant difference in the uptake of phosphorus or potassium between tillage treatments although there was a tendency for potassium to be lower in the corn on subsurface tilled plots.

Results in 1953

In 1953 a similar experiment was conducted at Ankeny, Iowa, but on a Nicollet silt loam soil. This soil occurs in association with the Webster soil used in 1952, but is lighter in texture and is found on gentle slopes in contrast to the flatter topography of Webster soil, and consequently has better surface drainage. Three rates of nitrogen fertilizer were used to study its effect on corn production under the different tillage methods. The treatments used and corn yields are presented in Table 4.

TABLE 4. EFFECT OF TILLAGE METHODS AND NITROGEN FERTILIZER ON CORN YIELDS GROWN ON NICOLLET SILT LOAM IN 1953

Tillage methods	Corn yields per acre, bu* Rates of nitrogen 80	160	240	Av.
Conventional plowing	115.9	122.8	119.7	119.5
Plowed - residue removed	122.5	125.8	112.8	120.4
Plowed - residue on surface	124.7	117.1	116.9	119.6
Subsurface tilled	113.1	115.8	121.8	116.9

*Yields are not significantly different. In addition to nitrogen all plots received 400 lb per acre 0-20-20 plus 140 lb per acre 4-16-8 (starter).

These data show that all corn yields were high, and that no significant differences resulted from different tillage methods. Analysis of young corn plants and of leaves collected at silking failed to show any difference in N, P and K content as a result of tillage. No microbiological studies were made.

Fertilizer rates used in this experiment are shown in Table 4. Nitrogen fertilizer (ammonium nitrate) was all broadcast just before planting. Phosphorus and potassium fertilizer was broadcast and plowed under on plowed plots and placed in bands 20 in apart and 3 to 7 in deep on subsurface-tilled plots. This made it possible to take advantage of deep placement of mineral fertilizer and also kept fertilizer placement as uniform as possible on all tillage treatments. Starter fertilizer was used on all plots since it is known to be especially advantageous where cool, moist soil conditions might be expected.

Adequate tilth and soil aeration apparently prevailed throughout the season even though two corn crops preceded the experimental crop. Soil oxygen determinations were made using essentially the method reported by Taylor (25). No differences due to tillage were found. Plowing and subsurface tillage were accomplished at a moisture content averaging 21.9 percent in the top 7 in of soil. This is approximately 10 percent below field capacity for this soil. At this moisture content excellent soil shattering and loosening was obtained with sweeps.

Corn stands were quite uniform on all treatments and averaged just over 18,500 plants per acre. Before planting, plots with surface residue were disked with the disk set straight. This broke clods and firmed the seedbed and still left most of the residue on the soil surface. Furrow openers were used on the corn planter and set just deep enough (2 to 3 in) to push trash aside and plant the corn in firm soil. This method of handling mulched plots has consistently helped to obtain good stands of corn.

Excellent weed control was obtained in all treatments. A pre-emergence spray was applied using 2,4-D and two cultivations were given.

The 1953 experiment had little value from the standpoint of isolating factors affecting corn yield under mulch tillage. However, it serves to demonstrate that when conditions are right, high corn yields can be obtained under mulch tillage, and they can be equal to those obtained with conventional plowing.

SUMMARY AND CONCLUSIONS

From the review of literature and the experimental results discussed in this report, the following summary and conclusions are presented:

1 Crop residue mulches tend to improve soil structure in the surface horizon. Also, they protect the surface layer of soil from the beating action of raindrops.

2 Soil moisture is frequently higher under mulched soils than under bare soils. This is due to a higher infiltration rate and a lower evaporation rate when mulch is present.

3 Soil temperatures are reduced by mulches. This reduction may be large with heavy applications of mulch, but is quite small when only the residue from the preceding crop is allowed to remain on the soil surface.

4 Soil tilth and aeration as factors affecting corn yields under mulch tillage appear to be important, but are difficult to measure and evaluate. In general, they vary in importance with soil type, seasonal conditions and tillage technique. Fine-textured soils and soils with poor natural structure and inferior drainage and aeration give the most trouble. Cool, wet seasons accentuate aeration problems. Subsurface tillage machines influence aeration through the degree of soil shattering or loosening accomplished. There undoubtedly are differences in the performance of subsurface tillers, but doing the tillage when soil moisture conditions are right may often be more important. A soil moisture content somewhat lower than considered satisfactory for plowing seems best.

5 The availability to plants of soil nitrogen and potassium is frequently lower under mulch tillage than with conventional plowing. Tillage practices appear to have little influence on the availability of phosphorus.

6 The availability of soil nitrogen appears to be more affected by the location of the mulching material than by the tillage tool used in preparing the seedbed. On the other hand, the availability of soil potassium is affected primarily by soil moisture conditions and tillage as they influence soil tilth and aeration.

7 Applications of fertilizer help to alleviate reduced availability of nitrogen and potassium under mulch tillage and increase corn yields. In some experiments when adequate fertility was present, corn yields under mulch tillage have been equal to those obtained with plowing. In other experiments this has not been true. This suggests that other unfavorable growth conditions were present, or that the amount and kind of fertilizer was inadequate, or that the placement of fertilizer was not right. More study is needed on fertilizer requirements for mulch tillage.

8 Mulch tillage influences the profile distribution of soil microorganisms. Microbial numbers and activity are greatest in the soil horizon containing the mulch or residue. When residues are placed on the soil surface or mixed in the top 3 in, decomposition is stimulated and the availability of nitrogen may be sharply reduced, especially during the first few weeks of decomposition. If corn growth is to proceed satisfactorily, there must be an adequate supply of nitrogen for both microbial activity and plant use.

9 Corn stands are frequently lower and weed populations higher under mulch tillage than under plowing. These factors must be controlled if fair yield comparisons are to be made between different tillage methods.

BIBLIOGRAPHY

1 Albrecht, W. A. Nitrate accumulation under straw mulch. *Soil Sci.* 14:299-305. 1922.

2 Albrecht, W. A. and Uhland, R. E. Nitrate accumulation under a mulch. *Soil Sci.* 20:253-267. 1925.

3 Alderfer, R. B. and Merkle, F. A. The comparative effects of surface application vs. incorporation of various mulching materials on structure, permeability, runoff and other soil properties. Soil Sci. Soc. Amer. Proc. 8 (1943):77-86. 1944.

4 Bennett, W. F., Stanford, G. and Dumenil, L. Nitrogen, phosphorus, and potassium content of the corn leaf and grain as related to nitrogen fertilization and yield. Soil Sci. Soc. Amer. Proc. 17:252-258. 1953.

5 Bower, C. A., Browning, G. M. and Norton, R. A. Comparative effects of plowing and other methods of seedbed preparation on nutrient element deficiencies in corn. Soil Sci. Soc Amer. Proc. 9:142-146. 1944.

6 Broadbent, F. Factors influencing nitrogen transformations in soils as determined by means of isotopic nitrogen. M. S. thesis, Iowa State College, 1946.

7 Dawson, R. C., Dawson, V. T. and McCalla, T. M. Distribution of microorganisms in the soil as affected by plowing and subtilling crop residues. Nebr. Agr. Expt. Sta. Res. Bul. 155. 1948.

8 Duley, F. L. and Russel, J. C. New methods of rainfall and soil moisture conservation. Annual report of Nebraska State Board of Agriculture:121-131. 1940.

9 Duley, F. L. and Russel, J. C. Using crop residues for soil defense. USDA Misc. Pub. 494:1-16. 1942.

10 Duley, F. L. and Russel, J. C. Stubble mulch farming to hold soil and water. USDA Farmers' Bul. 1997:1-32. 1948.

11 Englehorn, C. L., The effect of tillage methods on soil and moisture conservation and crop yields at Langdon and Adgeley. North Dakota Expt. Sta. Bul. 341:1-35. 1946.

12 Gamble, S. J. R., Edminster, T. W., and Orcutt, Fred S. Influence of double-cut plow mulch tillage on number and activity of microorganisms. Soil Sci. Soc. Amer. Proc. 16:267-269. 1952.

13 Hall, N. S. Root distribution and fertilizer placement. *Farm Chemicals.* 115:25-31. 1952. *(Continued on page 736)*

Drying Rice with Unheated Air

Stanton Morrison
Assoc. Member ASAE

RICE of higher milling quality is obtained if it is harvested at a moisture content above that at which it can be safely stored. It is usually harvested when it contains 16 to 24 percent moisture, whereas the maximum moisture content for safe storage is 12 to 14 percent.

Since the time that the combine came into general use, the bulk of the crop has been dried in column-type continuous-flow driers using heated air. The rice was then sold or put in commercial storage. Because of a shortage of commercial storage and an interest in drying and storing on the farm, research was undertaken at the Rice Pasture Experiment Station, Beaumont, Tex., to determine the practicability of drying rice in storage bins in quonset buildings and similar structures. Tests using both heated air and unheated air have been conducted. Drying in bins with unheated air has certain advantages as compared with heated air. Among them are lower equipment cost, less attention required, less fire hazard, less stratification of moisture and little likelihood of overdrying the grain.

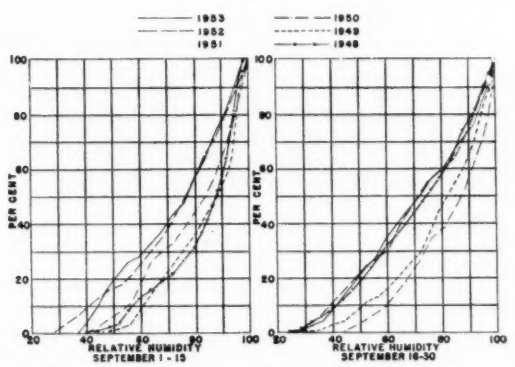


Fig. 1 Percent of time relative humidity was indicated value or less (Beaumont, Tex.)

Tests were carried out using 500 to 550-bbl bins in a 32-ft and a 16-ft quonset. (One barrel weighs 162 lb and is equal to 3.6 bu.) The results proved encouraging so small-scale tests were conducted to obtain information on optimum air-flow rates and operating procedure. The results of the small-scale tests using unheated air are reported in this paper.

Weather Conditions

A disadvantage of using unheated air is the dependence upon favorable weather conditions for satisfactory drying. A study of weather conditions of the Beaumont area, particularly with respect to relative humidity, was made to determine if unheated air drying could be relied upon. It was also desirable to know how the weather which prevailed during any test compared with that normally expected for that period. An example of the results of this study is shown in Fig. 1. From these curves the amount of time the relative humidity was within any given range during the 15-day period may be obtained. The farther to the left a curve is, the drier the weather was during that period. Similar curves were obtained for four other months. Out of 60 periods analyzed every one except one had relative humidity at or below 80 percent at least 25 percent of the time. The one exception occurred when a Gulf hurricane affected the area.

Equipment

The bins, 30 in square and 8 ft deep, were constructed of plywood with a 2 x 4 framework. They were placed in one end of a 32-ft quonset with blowers located to draw air from the outside. The air-flow rate to each bin was controlled by an orifice and an adjustable gate. Each bin had thermocouple junctions spaced along the vertical center line at one foot from the bottom, center, and one foot from the top. Sampling ports were placed near the bottom and at the center.

Test Procedure

The rice used in these tests was loaned by farmers in the area. Samples from three levels in all bins at the start of the tests were air dried in thin layers in trays and used as checks. Moisture determinations were made with a Brown-Duvel moisture tester every two to seven days. Temperature and pressure readings were taken periodically. Four air-flow rates were used and were calculated from the pressure drop across the orifices. The blower on one set of four bins was controlled by a humidistat set at 75 percent relative humidity. The blower on the other four bins was operated continuously. Air was pushed up through the bins.

Results

Two tests were conducted in 1953. The rice used in the first test was relatively dry. The rate of moisture reduction is shown in Fig. 2. There was little variation of moisture throughout any bin. Operating time for the intermittent operation was approximately 50 percent of total time. These results indicate that rice in this range of moisture may be dried faster with intermittent operation. The advantage is greatest with the higher air-flow rates. The composite sample taken from every bin at the end of the test showed an increase in percent of head rice over the check sample. There was no significant change in germination.

The results of the second test are shown in Figs. 3 and 4. Operating time for the blowers on the bins which received intermittent operation was approximately 30 percent of total time. Faster drying was obtained with continuous operation at all air-flow rates. There was also less variation in moisture with this procedure. A minimum air-flow rate of 6.7 cfm per barrel is indicated from this test. However, the recommended rate should be somewhat higher to take

Abridged paper presented at a joint meeting of the Southwest and Southeast Sections of American Society of Agricultural Engineers at Dallas, Tex., February, 1954.

The author—STANTON MORRISON—formerly assistant agricultural engineer, Rice Pasture Experimental Station, Beaumont, Tex., is presently rice officer, Department of Agriculture, Belize, British Honduras.

Acknowledgment: The author expresses appreciation to J. W. Sorenson, Jr., agricultural engineering department, A. and M. College of Texas, for advice and cooperation in planning and conducting the tests reported in this paper.

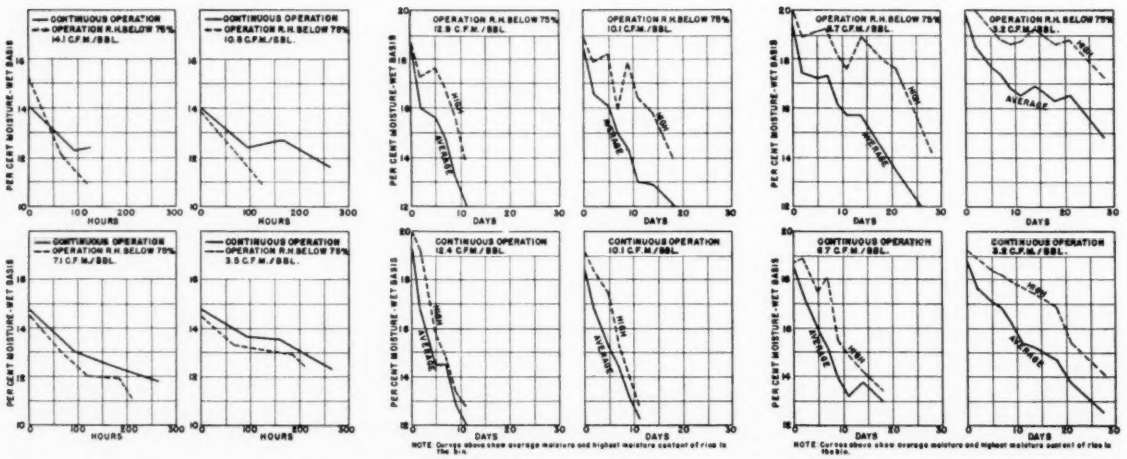


Fig. 2 *(Left)* Moisture content during drying of rice in bins 8 ft deep using unheated air. Test started Sept. 9, 1953 • Fig. 3 *(Center)* Moisture content during drying of rice in bins 8 ft deep using unheated air. Test started Oct. 19, 1953 • Fig. 4 *(Right)* Moisture content during drying of rice in bins 8 ft deep using unheated air. Test started Oct. 19, 1953.

into consideration more severe weather and rice with higher initial moisture content.

The rice in the bin with intermittent operation at the lowest air-flow rate was dried after two months time. At one time the rice in the top of the bin had a musty odor, but this disappeared and the final milling test showed no loss in quality. Of a total of 24 samples taken for the final milling tests all but one showed an increase in head rice with an average increase of 3.6 lb per 100 lb. The germination increased from an average of 85.6 to 91.5 percent.

Summary and Recommendations

Tests at Beaumont, Tex., indicate that rice can be dried using unheated air under weather conditions of the Texas rice belt. It will be necessary, though, for the operator to follow certain procedures for best results. The following recommendations are made on the basis of all the tests conducted at Beaumont:

1 Dry rice with at little foreign material as possible, and fill the bin to prevent "trash" from accumulating in pockets.

2 Fill bins to a maximum depth of 10 ft if the rice contains less than 18 percent moisture and 8 ft if the moisture content is above 18 percent.

3 Select ventilation equipment which will provide an air-flow rate of not less than 7.5 cfm per bbl with a recommended rate of 9.0 cfm per bbl.

4 Start the blower as soon as possible after the air ducts are uniformly covered with rice.

5 Push air through the rice continuously, except when a period of extremely high humidity last longer than 24 hr. During such periods, operate the blower 2 to 3 hr each day to prevent heating until the weather clears. Continue with this procedure until the moisture content of the top foot of the rice is reduced to about 16 percent. Then push air only when the outside relative humidity is 75 percent or less. When the moisture content of the rice in the middle layer of the bin is 14 percent or less, reverse the blower and pull air down through the rice, until the moisture is not more than 13½ percent (12½ percent for storage over 6 months) in any part of the bin. During the period when air is pulled through the rice, operate the fan when the relative humidity is 75 percent or less.

6 Aerate during storage by pulling air down through the rice when the outside temperature is 10F or more below the average grain temperature and outside relative humidity is 80 percent or less.

Effects of Mulch Tillage

(Continued from page 734)

14 Hoagland, D. R. and Broyer, T. C. General nature of the process of salt accumulation by roots with descriptions of experimental methods. *Plant Phys.* 11:471-507. 1936.

15 McCalla, T. M. and Duley, F. L. Disintegration of crop residues as influenced by subtillage and plowing. *Jour. Amer. Soc. Agron.* 35:306-315. 1943.

16 McCalla, T. M. and Duley, F. L. Effect of crop residues on soil temperature. Jour. Amer. Soc. Agron. 38:75-89. 1946.

17 McCalla, T. M. and Russel, J. C. Nitrate production as affected by grain-crop residues on the surface of the soil. Nebr. Agr. Expt. Sta. Res. Bul. 131. 1943.

18 McCalla, T. M. and Russel, J. C. Nitrate production as affected by sweetclover residues left on the surface of the soil. *Jour. Amer. Soc. Agron.* 40:411-421. 1948.

19 Moody, J. E., Lillard, J. H. and Edminster, T. W. Mulch tillage: same effects on plant and soil properties. Soil Sci. Soc. Amer. Proc. 16:190-194. 1952.

20 Page, J. B., Willard, C. J. and McCuen, G. W. Progress report on tillage methods in preparing land for corn. Soil Sci. Soc. Amer. Proc. 11 (1946):77-80. 1947.

21 Pepkowitz, L. P. and Shive, J. W. The importance of oxygen in the nutrient substrate for plants-ion absorption. *Soil Sci.* 57: 143-154. 1954.

22 Scott, Hershel. The influence of wheat straw on the accumulation of nitrates in the soil. *Jour. Amer. Soc. Agron.* 13: 233-258. 1921.

23 Stallings, J. H. Keep crop residues on the surface of the ground. USDA, SCS-TP-80. May, 1949.

24 Stephenson, R. E. and Shuster, C. E. Effects of mulches on soil properties. *Soil Sci.* 59:119-130. 1945.

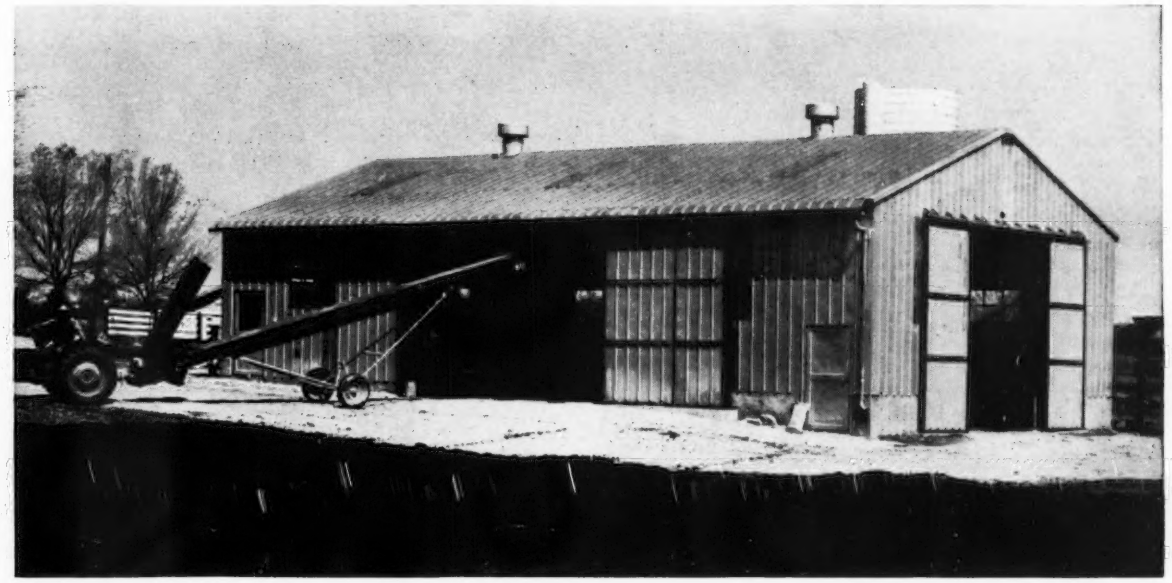
25 Taylor, G. S. and Abrahams, J. H. A diffusion-equilibrium method for obtaining soil gases under field conditions. Soil Sci. Soc. Amer. Proc. 17:201-206. 1953 .

26 Tyner, E. H. The relation of corn yields to leaf nitrogen, phosphorus and potassium content. Soil Sci. Soc. Amer. Proc. 11: 317-323. 1946.

27 Verma, A. B. S. and Kohnke, H. Effects of organic mulches on soil conditions and soybean yields. *Soil Sci.* 72:149-156. 1951.

"My steel building is the most adaptable I've ever used"

says F. R. Adams of Lenexa, Kansas



MR. ADAMS has found a variety of uses for his 36′ x 60′ x 12′ steel building. "This new steel building is just the thing for machine storage," he says. "We can take any machine on the farm through those 20-foot-wide sliding doors. And my steel building is just right for livestock, too," continues Mr. Adams. "It's weathertight, easy to partition, and it's simple to keep clean."

Steel buildings give maximum, unbroken floor area because there are no upright columns in the middle of the floor. Machinery can be moved freely about without having to jockey around supporting posts. Furthermore, steel buildings are fire-resistant. And their sturdy construction resists the forces of strong winds and hard usage. No doubt about it—steel is the ideal material for farm buildings, because steel buildings give exceptionally long service at the lowest maintenance cost.

Farmers and dairymen will tell you—you get the most for your money when you invest in a Factory-Built Steel Farm Building manufactured with long-lasting USS Galvanized Steel Sheets for roofs and walls, and a USS Structural Steel framework.

● **When buying a Factory-Built Steel Farm Building, ask for USS Galvanized Steel for roofs and sides. This product has a certified galvanized coating produced to ASTM Specification A-361. This is your assurance of a high quality building.**

USS

4-1075 A

Agricultural Extension Section
United States Steel Corporation
Room 4360, 525 William Penn Place
Pittsburgh 30, Pa.

I am interested in steel buildings for the following:

☐ machinery storage ☐ cattle shelters ☐ grain storage
☐ dairy barns ☐ hay storage ☐ poultry houses
☐ other.....

Approximate size or capacity.....

☐ **Please have a Steel Building representative call on me with further information.**

Send information to:

Name.....

Address.....**Town**.....

County.....**State**.....

United States Steel Corporation produces high-quality USS Galvanized Sheets and Structural Steel which our customers manufacture into durable farm buildings. Your requests for information will be forwarded to the manufacturers of these buildings, and you will hear directly from them.

UNITED STATES STEEL

INSTRUMENT NEWS

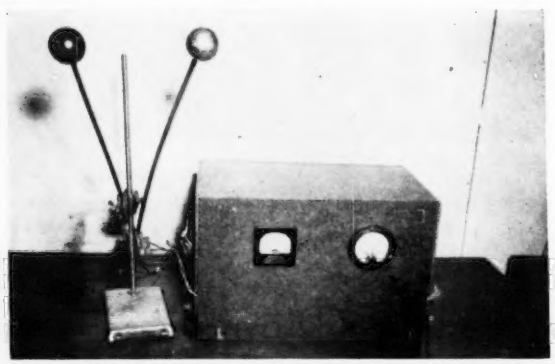
KARL NORRIS, Editor

Sponsored by the ASAE Committee on Instrumentation and Controls. Contributions on agricultural applications of instruments and controls and related problems are invited, and should be submitted direct to K. H. Norris, Agricultural Research Center, Beltsville, Md.

The Two-Ball (Total Spherical) Radiometer

R. V. Dunkle and J. T. Gier

THE radiation heat load is very important in the study of environmental effects on farm animals. As the animal is three dimensional, one is concerned with radiation arriving from all directions, and it is thought that the total spherical radiation (total radiation falling upon a sphere of unit area) is a valid indication of the radiation load upon an animal in the same environment. Following the suggestion of C. F. Kelly, University of California, Davis, and T. E. Bond, U.S. Department of Agriculture, the two-ball, total spherical radiometer (Fig. 1) was designed to measure the total radiant energy from the surrounds. Briefly, the principle of its operation is as follows: If two spheres, one with a high absorptivity (blackened) and another with a low absorptivity (silvered), are exposed



The two-ball, total spherical radiometer designed by the authors

to radiant energy, the one with a high absorptivity will absorb more energy than the other. Additional heat is supplied to maintain the spheres at equal temperature and is a measure of the radiant energy. Heat losses, other than by radiation, from the two spheres are equal since the spheres are at equal temperatures.

The control system is designed to automatically keep the spheres at equal temperatures. A copper-constantan thermocouple is affixed to each of the spheres. The thermocouples are connected in opposition and the difference in voltage is utilized to control the heat input to the silver sphere. When the silver sphere is colder than the blackened sphere, a positive signal results, and, conversely, when the silver sphere is warmer, a negative signal results.

The signal from the thermocouples is fed into a power amplifier which drives a balance motor. Depending on the polarity of the input signal the motor is driven either clockwise or counterclockwise. The motor drives two rheostats, one which is used to introduce a small bucking voltage into the thermocouple circuit and the other to vary the power input to the silver sphere.

When a positive voltage (silver sphere colder) is fed into the power amplifier, the motor drives the rheostats and more power is supplied to the silver sphere. When the two spheres reach equal temperature there is no input to the amplifier and the motor remains motionless. If a negative voltage is fed into the system, the power to the silver sphere is reduced.

The small variable bucking voltage is introduced into the thermocouple circuit to reduce overshooting the balance point and to increase stability. The further from balance the system is, the greater this input, which prevents excessive unbalance and reduces cycling. This voltage makes it possible to reach a balance point even though the spheres are not exactly at the same temperature. The error due to this has been calculated and the results show that it is negligible.

The current input to the black sphere is held constant at a predetermined value and the current input to the silver sphere determined by recording the voltage drop across a fixed resistance. The temperature of the balls is also obtained by the recorded output of the thermocouple in the black sphere.

An energy balance performed on the system reveals an equation for computing the total radiation as follows:

$$G_t = \sigma T^4 + K(I_2^2 - I_1^2)$$

where G_t = total irradiation in Btu/(hr)(ft²) received from all of space

σ = Stefan-Boltzmann radiation constant = 1.714×10^{-9} Btu/(hr)(ft²)(deg R⁴)

K = constant for system involving absorptivities and areas of spheres and conversion factors

I_2 = current to silver ball in amperes

I_1 = current to black ball in amperes

T = temperature of balls (black ball), deg R.

The authors—R. V. DUNKLE and J. T. GIER—are, respectively, associate professor of mechanical engineering and associate professor of electrical engineering, University of California (Berkeley).

Cheaper Irrigation Ditches

Western Nebraska farmers have developed a new and cheaper way to build and maintain irrigation ditches—by mounting used highway snowplows on their track-type tractors. This picture shows a Caterpillar D6 tractor on which snowplow blades has been installed. The blades are hydraulically controlled and the lower portion is cut to a 35-in ditch bottom width

"JUST RIGHT for diversion ditches and terraces,"

SAYS GORDON J. GIBSON, CONTRACTOR

Right size, speed, balance and traction combine to make the Allis-Chalmers Model D Motor Grader a natural for building terraces and diversion ditches, according to Gordon J. Gibson, Claremore, Okla., contractor.

Mr. Gibson, who specializes in earth moving for conservation projects, finds he can build a terrace in just 13 rounds with the Model D. It takes the same number of rounds — sometimes more — with larger, less maneuverable motor graders.

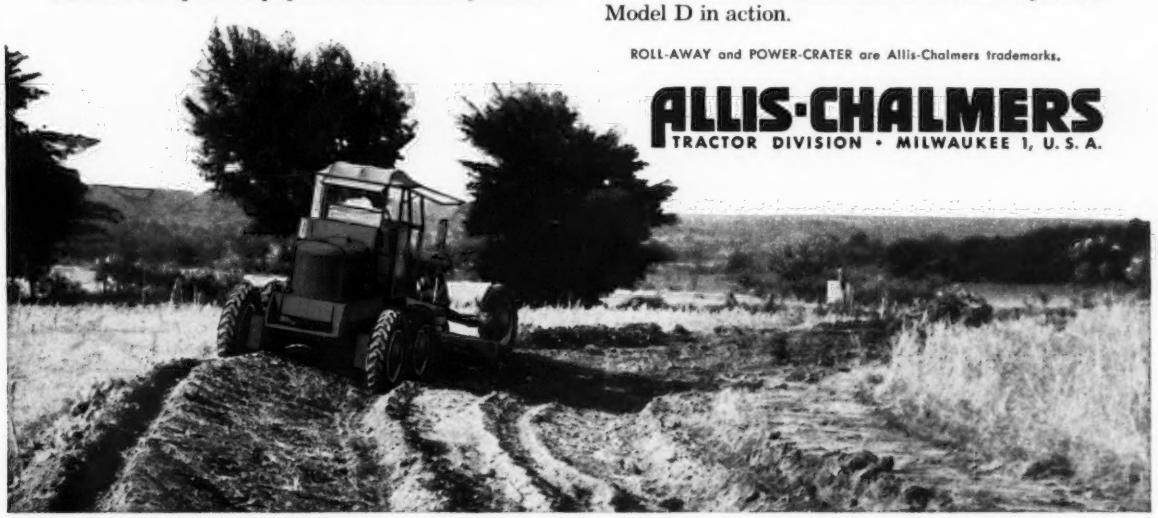
In addition, the flexible Model D can work close to fence lines and deep into the corners, eliminating the need for special equipment. Accurate hydraulic blade control and exclusive ROLL-AWAY moldboard permits smooth finishing so that farmers can cross contours with farm machinery.

The Allis-Chalmers Model D Motor Grader weighs 8,800 lb, travels at speeds up to 25.6 mph, and is powered by the famous 50-hp POWER-CRATER gasoline engine. It has all the essential design features of large motor graders, yet costs only one-third as much. Special equipment includes power circle turn, leaning front wheels, mid-ship scarifier, rear-end hydraulic loader, and snowplow.

Write for complete literature or ask your Allis-Chalmers industrial tractor dealer to show you the Model D in action.

ROLL-AWAY and POWER-CRATER are Allis-Chalmers trademarks.

ALLIS-CHALMERS
TRACTOR DIVISION • MILWAUKEE 1, U. S. A.



NEWS SECTION

Preview of Program for the 1954 ASAE Winter Meeting

DECEMBER 6, 7, and 8 are the dates of this year's winter meeting of the American Society of Agricultural Engineers. The location of the meeting is the Edgewater Beach Hotel, Chicago. The executive committees of the Society's four technical divisions — Power and Machinery, Soil and Water, Farm Structures, and Rural Electric —are presently in the process of completing arrangements with an array of speakers, whose choice of subjects and professional background provides abundant assurance for all who will attend the meeting that the program will be at least equally as interesting and informative as any of the ASAE winter meetings previously held during the 30 years since they were inaugurated.

ASAE members are being supplied with means for making advance guestroom accommodations at the Edgewater Beach Hotel, and non-members interested in attending the meeting should communicate with the central office of the Society at St. Joseph, Michigan, for copies of the hotel reservation form and the program of the meeting sessions.

The main feature of the meeting will be, as usual, the technical programs arranged by the Society's four technical divisions. In addition, the Education and Research Division is arranging a half-day program that will be of particular interest to all agricultural engineers whether in industry, state, federal, or private employ. Following are the highlights of the program in the present stage of preparation:

Power and Machinery Program

The presiding chairman of the first session of the power and machinery program, on Monday forenoon, December 6, will be the chairman of the Power and Machinery Division, Roy Bainer (chairman, agricultural engineering department and assistant dean of engineering, University of California). The program for the session will open with a paper on high-speed photography as an aid in farm machinery design by E. C. Carlson, chief engineer, and R. B. Barnick, photographer, advanced engineering department, International Harvester Co. This will be followed by a paper on instrumentation for stress analysis to be presented by Stanley D. Gralak, supervisor, stress analysis division, materials engineering department, Deere & Co. The concluding paper of the session will be presented by L. H. Schoenleber, engineer in charge of the central testing laboratory, J. I. Case Co., on the use of strain gages and stress coats in farm machinery design.

Presiding at the afternoon session on Monday, December 6, will be the vice-chairman of the Power and Machinery Division, Byron T. Virtue (sales manager, bearings division, The Torrington Co.). The first scheduled speaker at this session will be W. S. Horsefield, chief engineer, Whitney Chain Co., whose subject will be "Improving the Fatigue Life of Roller Chains." The second speaker on this program will be Clarence A. Hubert, manager of engineering, farm tractor division, International Harvester Co., who will discuss the "Electrall" system, the experimental electric generating unit mounted on a current model of the Farmall tractor which gives promise of developing new techniques in the application of power to agriculture. The third speaker at this session will be John B. Liljedahl, a member of the agricultural engineering staff of Purdue University, who will discuss the use of mechanical energy in soil strip weed control. This will be the concluding paper of the session.

At the forenoon session on Tuesday, Dec. 7, the presiding chairman will be the junior past-chairman of the Power and Machinery Division, George M. Eveleth (chief engineer, Rock Island Works, J. I. Case Co.).

The first paper on the program of this session is titled "Mechanical Aids for Harvesting and Pruning Trees" and is authored by Fred Hill and Robert W. Brazelton, Blackwelder Manufacturing Co. The second paper will be presented by H. D. Bruhn, professor of agricultural engineering, University of Wisconsin, and is titled "Present Status in the Development of Hay Crushers." The concluding paper of this session will report a laboratory and field study of power requirements of the forage harvester and will be presented by F. Z. Blevins of the Allied Chemical and Dye Co. and previously on the agricultural engineering staff of Purdue University, and H. J. Hanson, also of the Purdue staff.

Vice-chairman Byron T. Virtue will preside at the forenoon session on Wednesday, December 8, which will open with a paper titled "The Semiself-Propelled Machine — A New Concept in Harvesting Machines" to be presented by R. W. King and Brantford G. Elliott, project engineers of Massey-Harris-Ferguson, Inc.

The second paper on this program will be a progress report on studies at the Ohio Agricultural Experiment Station on drying and storage of combined wheat to be presented by Homer T. Hurst, agricultural engineer. N. B. Akesson and W. E. Yates, agricultural engineers, University of California, are listed as authors of the third paper on this program entitled "Air Wake Characteristics of Agricultural Aircraft." This will be followed by a paper presenting a summary of wind tunnel studies of distributors for agricultural aircraft by James E. Henry of Ohio State University. The concluding paper on this program will be presented by Austin A. Armer, agricultural engineer, Spreckels Sugar Co., which will discuss European equipment and practices in root harvesting.

Chairman Roy Bainer will preside at the concluding half-day program to be presented by the Power and Machinery Division, on Wednesday afternoon, December 8. The entire session will be devoted to the subject "Hydraulic Power Transmission." The subject will be discussed in relation to its application to the agricultural implement and tractor field. Three phases of the general subject will be covered, namely, hydraulics in power transmission, characteristics of hydraulic-power transmission, and application of hydrostatic-power transmission. The three speakers to be announced who will present these three different phases of the subject will be representatives of Vickers Division of The Sperry Corp., Hydreco Division of The New York Air Brake Co., and the Berry Division of Oliver Iron and Steel Corp.

Soil and Water Program

The Soil and Water Division has planned a program featuring a half-day session arranged by each of its four group chairmen, and meetings of its several committees.

T. W. Edminster, chairman of the Division, is to preside at the opening session, Monday forenoon, December 6. The program on the general subject "Engineering Erosion Control Practices" was arranged by John R. Carreker, chairman of the Soil Erosion Group.

Subjects and speakers scheduled are "A Study of Parallel Terracing" by Howard D. Wittmuss, University of Nebraska; "Runoff and Erosion in the Upper Mississippi Valley" by Orville E. Hays, Agricultural Research Service, USDA; "The Effects of Rainfall Characteristics on Soil Losses from Cotton" by A. P. Barnett, Agricultural Research Service, USDA, and University of Georgia, and "Some Engineering Aspects of Soil Management for Erosion Control" by M. L. Nichols, Agricultural Research Service, USDA.

The Monday afternoon program, on irrigation, was arranged by Wayne D. Criddle, chairman of the Irrigation Group; Ernest H. Kidder, chairman of the Committee on Sprinkler Irrigation Research, will preside. (Mr. Criddle received an unexpected temporary foreign-duty assignment after arranging the program and the date of his return is somewhat uncertain.) Papers tentatively scheduled are "Linings for Small Irrigation Reservoirs and Farm Ditches" by V. H. Scott, department of irrigation, University of California; "Pasture Studies in Southern Illinois" by B. A. Jones, University of Illinois; "Irrigation Studies on Pasture and Other Crops at Hartley, Montana" by O. W. Monson, Montana State College; "Design of Sprinkler Systems for Pasture" by W. D. Howell, Choctaw, Inc.; "Progress Report of the Committee on Sprinkler Irrigation Research" by Ernest H. Kidder, and "Progress Report of the Committee on Specifications for the Installation of Concrete Irrigation Pipe" by Milo W. Hoisveen.

The Hydrology Group program is scheduled for Tuesday forenoon, December 7,

(Continued on page 742)

ASAE Meetings Calendar

October 14 and 15 — PACIFIC NORTHWEST SECTION, Davenport Hotel, Spokane, Wash.

October 23 — MICHIGAN SECTION, Agricultural Engineering Building, Michigan State College, East Lansing

November 4 and 5 — GEORGIA SECTION, Dinkler-Plaza Hotel, Atlanta, Ga.

November 5 — IOWA-ILLINOIS SECTION, American Legion Club, East Moline, Ill.

December 6-8 — WINTER MEETING, Edgewater Beach Hotel, Chicago.

February 7-9—SOUTHEAST SECTION, Brown Hotel, Louisville, Ky.

June 12-15, 1955—48TH ANNUAL MEETING, University of Illinois, Urbana

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

"Service Station" on wheels saves time

L. F. Nelson (right) shows Texaco Man Roy Stubbs of Davenport, Washington, his "service station" on wheels. Mr. Nelson lubricates his equipment in the field with Marfak lubricant because it sticks to bearings better and longer, seals out grit and dirt, won't wash off, jar out, dry out or cake up.

L. F. NELSON, prominent farmer, near Davenport, Washington, who raises 1,500 acres of wheat, finds that he saves a lot of valuable time during harvesting operations by lubricating his equipment in the field. In the back of his pick-up truck he carries a compressor with twenty feet of hose and Marfak lubricant.

After operating his tractor for eight years, he pulled out a roller and found the bearing in perfect condition, thanks to Marfak lubricant.

Mr. Nelson has been using nothing but Texaco Products for more than twenty years. He uses Advanced Custom-Made Havoline and Ursa Heavy Duty Motor Oils, Universal Gear Lubricant EP, Diesel Chief, and Fire Chief Gasoline, besides Marfak.

Like Texaco Men the country over Roy Stubbs *(right)* gives on-time, neighborly service. Mr. Nelson is "filling up" his Caterpillar with Diesel Chief, the fuel that gives superior power in diesel motors, ensuring low-cost operation.

M. S. Knowlton, (left), Director of the Delta Council, operates a 3,500-acre plantation near Perthshire, Mississippi, with twenty-seven tractors and other farm equipment. Advanced Custom-Made Havoline Motor Oil with an exclusive formula of Balanced Additives wear-proofs engines, keeps them clean and free from sludge, corrosion and rust. Texaco Man C. M. Shaw, Jr., Shelby, Mississippi *(right)*, serves Knowlton Plantation.

In town or on the highway, farmers and ranchers find Texaco Dealers give friendly, helpful service. Only Texaco Dealers have new top octane Sky Chief gasoline, Super-Charged with Petrox, to give maximum power and reduce engine wear . . . and famous Fire Chief, at regular prices, both 100% *Climate-Controlled* for top performance. You can also get Advanced Custom-Made Havoline, the motor oil that wear-proofs engines for longer life.

THE TEXAS COMPANY

TEXACO

ON FARM AND HIGHWAY IT PAYS TO USE TEXACO PRODUCTS

DIVISION OFFICES: Atlanta 1, Ga.; Boston 17, Mass.; Buffalo 3, N. Y.; Butte, Mont.; Chicago 4, Ill.; Dallas 2, Tex.; Denver 5, Colo.; Houston 1, Tex.; Indianapolis 1, Ind.; Los Angeles 15, Calif.; Minneapolis 3, Minn.; New Orleans 12, La.; New York 17, N. Y.; Norfolk 1, Va.; Seattle 11, Wash.

Texaco Petroleum Products are Manufactured and Distributed in Canada by the McColl-Frontenac Oil Company Limited.

NEWS SECTION

(Continued from page 740)

with Howard Matson, group chairman, presiding. Two papers scheduled are "Sedimentation in Small Watersheds" by Russell Woodburn, Agricultural Research Service, USDA; and "Development of Infiltration Data from Small Watersheds," by William F. Lytle, University of Illinois.

A symposium on water pumping and distribution is featured for the remainder of the session. It will consist of a series of four off-the-cuff talks, followed by a discussion period. This part of the program was arranged by G. E. Trisler, The Deming Co., who with K. L. McFate, Iowa State College, will lead the discussion with "Recent Developments in Pumping Equipment." Succeeding talks are "Use of Submersible Pumps with Above-Ground Disposal Systems" by Arthur H. Schultz, North Dakota State College"; Water Supply for Rural Schools, Motels and Other Tourist Accommodations," by W. H. Sheldon and Clair Gunn, Michigan State College; and "Plastic Pipe for Use with Jet Pumps and Deep-Well Submersibles and for Irrigation and Sewer Pipe," by Walter Prendergast, Carbon Products Corp.

Drainage subjects are to be presented at the Wednesday forenoon (December 8) session with Keith H. Beauchamp, chairman of the Committee on Specifications for Design and Construction of Tile Drains, presiding. John G. Sutton, chairman of the Drainage Group, arranged the program. Papers scheduled are "Subsurface Drainage with Perforated Plastic Tubes" by Glen O. Schwab, Iowa State College; "Design Features of Surface Drainage Systems for Slopes Up to Four Per Cent" by A. J. Wojta, University of Wisconsin; "Drainage Systems for Sloping Irrigated Lands" by W. F. Long, Soil Conservation Service, USDA, and "Laboratory Studies on Gravel Filters for Wells, Well Screens, Draintile, etc.," by Norman Evans, Colorado A & M College.

Meetings of the Steering Committee of the Soil and Water Division are scheduled for Monday evening and Wednesday afternoon. Other committees of the Division are to meet on Tuesday evening.

Farm Structures Program

Engineering factors influencing animal shelter design are to be featured in one session of the Farm Structures Division. C. H. Jefferson, chairman of the Division, will preside. Indicated subjects and speakers are "Hot Weather Shelters for Lactating Dairy Cattle" by G. L. Nelson, Oklahoma A & M College; "Influence of Solar Radiation on the Design of Dairy Shelter" by Robert E. Stewart, University of Missouri; "Cooling Beef Cattle Shelters in Hot Climates" by C. F. Kelly, University of California, and "Poultry House Design for Hot Climates" by George Quigley, University of Maryland.

Feed storage and handling, with emphasis on silage and green feed, will be dealt with in another session, with C. F. Kelly, vice-chairman of the Division, presiding. The papers of this session are to include "Horizontal Silos Save Feed and Labor" by W. D. Hunnicutt, National Dairy Products Corp.; "Lateral Pressures of Silage as Packed in Horizontal Silos" by Merle Esmay, University of Missouri, and "Feeding Green Chopped Forage" by Geo. T. McCutcheon, New Holland Division, Sperry Corp.

At the same session a symposium on "Covering Materials for Horizontal Silos" will feature talks on "Effectiveness of Plastic Sheet Covers" by C. H. Reed, Rutgers University, and by W. A. Cowan, University of Connecticut, and "Covering Materials and Losses from Horizontal Silos" by Wallace Ashby, U.S. Department of Agriculture.

A session on "Engineered Dairy Structures" arranged by Cameron Hervey, Hervey Research Development Corp., will feature five short talks and a concluding panel discussion with the speakers all available to answer questions. Mr. Hervey will preside and open the program with a contribution on "A Totally Engineered Farm Milk Plant." This will be followed by "Influence of Bulk Handling on Dairy Building Design" by Luke Nolan, Mojonnier Bros.; "Influence of Pipe Line Milkers on Dairy Building Design" by H. B. Bradshaw, DeLaval Separator Co.; "What Sanitarians Want in Dairy Buildings and Equipment" by Paul Hanger, Illinois department of Public Health, and "What Dairy Farmers Want in Buildings and Equipment" by Donald Rupert, dairy farmer, New Waterford, Ohio. Questions and discussion from the floor will be held to the open period following the talks.

Rural Electric Program

The Rural Electric Division will present three half-day programs and will also participate in a joint session with Farm Structures on agricultural processing, Carl W. Hall, chairman, Committee on Agricultural Processing, and associate professor, Michigan State College, will be chairman of this session.

W. J. Ridout, Jr., editor, *Electricity on the Farm Magazine*, and chairman of the Division, will preside at the Monday forenoon session, December 6, which will include the following subjects and speakers: "Progress Toward the Establishment of a Single Standard for Fence Controllers" by F. W. Duffee, University of Wisconsin; "Grounding of Cord-Connected Appliances and Equipment" by Morris H. Lloyd, Niagara Mohawk Power Corp.; "What Are Electrical Contractors Doing About the Farm Wiring Problem," by a representative of the National Electrical Contractors Association, and "Phase Converters and Their Application to Farms" by L. B. Ronk, System Analyzer Corp.

Subjects and speakers for the Monday afternoon program are "A Critical Appraisal of Present-Day Electrical Equipment for Poultry Production" by A. W. Brant, ARS, USDA, "What's New in Egg Cooling" by R. C. Jaska, A & M College of Texas, and Jack Dewitt, Automatic Poultry Feeder Co., and "Existing and Projected Research on Uses for Heat Pumps on Farms" by H. A. Cloud, University of Minnesota. H. S. Pringle, rural electrification specialist, Federal Extension Service, U.S. Department of Agriculture, and vice-chairman of the Division, will preside at this afternoon session.

At the third session, Chairman Ridout will introduce the following speakers and subjects: Kenneth Harkness, Kansas State College, on "Automatic Grinding and Blending of Ear Corn and Small Grains"; John Dobie, University of California, on "A Summary of Mechanical Feeding Work in California"; E. G. Schneider, University of Vermont, on "Mechanical Feeding of Cows in Stanchions," and John E. Nicholas, Pennsylvania State University, on "Fundamental Performance of Bulk Milk Coolers."

Education and Research Program

Tuesday afternoon, December 7, has been reserved for a special program of wide interest being developed by the Education and Research Division, formerly the College Division of the Society. Frank W. Peikert, division chairman, will preside.

Stanley M. Madill (past-president, ASAE), John Deere Waterloo Tractor Works, will speak on "In-Service Training Programs for Agricultural Engineers."

Arrangements are being made with other representatives of industry to speak on techniques for developing interest and on research methods and techniques. The subject of cooperation between universities and industries is to be presented by a representative of each field.

If time permits, a contribution on youth programs will be included at this session.

ASAE Michigan Section Offers Interesting Program

THE next meeting of the Michigan Section of the American Society of Agricultural Engineers will be held in the agricultural engineering building, Michigan State College, East Lansing, on October 23. Following registration, which begins at 9:30 a.m., the program will open with a discussion of hydrocooling and transportation of tart cherries in water, by J. H. Lewis, USDA agricultural engineer stationed at MSC. This new method of handling cherries reduces the cost while maintaining quality.

James L. Child, Jr., sales manager, Hancock Brick and Tile Co., will talk on the engineering aspects of the manufacture of vitrified shell draintile. The talk will be accompanied by a short movie on the manufacture of tile and it will be concluded with a brief summary of the application of shell draintile to the conditions of Michigan agriculture.

A discussion titled "Turbos for Tractors" covering the advantages and disadvantages of possible application of gas turbines for powering tractors, will be presented by Andrew Kucher, director of the scientific laboratory of the engineering staff of Ford Motor Co. L. L. Otto of the engineering school of Michigan State College will lead the discussion of Mr. Kucher's talk.

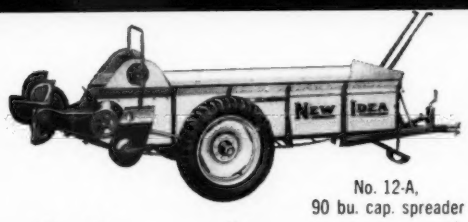
Arrangements are being made for a social hour for the ladies accompanying their husbands and others to the meeting, in the agricultural engineering building during the forenoon technical session. A luncheon will be served for members and guests with Section Chairman K. L. Pfundstein presiding. The meeting will adjourn for the football game between MSC and Purdue University in the afternoon.

Agricultural Engineering in ALGCU Program

FOUR papers on agricultural engineering are scheduled on the program of the Engineering Instruction Division, at the annual meeting of the Association of Land-Grant Colleges and Universities. The meeting is to be held at Columbus, Ohio, Novemer 10 to 12 .

The papers scheduled are "Administration of Agricultural Engineering" by H. B. Walker, University of California; "Undergraduate Curriculums in Agricultural Engineering" by J. Roberts, State College of Washington; "Graduate Study in Agricultural Engineering" by Orval C. French, Cornell University, and "Laboratory Facilities in Agricultural Engineering" by A. W. Farrall, Michigan State College. Any interested members of the ASAE are especially invited to attend this session.

(Continued on page 744)



No. 12-A,
90 bu. cap. spreader

NEW IDEA

Manure Spreaders

work better, faster... last longer!

You Can't Beat 'Em (4 sizes)

...on Medium Size Farms

For the medium or average size farm the NEW IDEA No. 12-A spreader fills the bill. It gives 90 bushel capacity and like the other NEW IDEA spreaders has a flared, non-choking bed for extra load. Adjustable tractor hitch and foot support mean easier hitching.

...on Smaller Farms

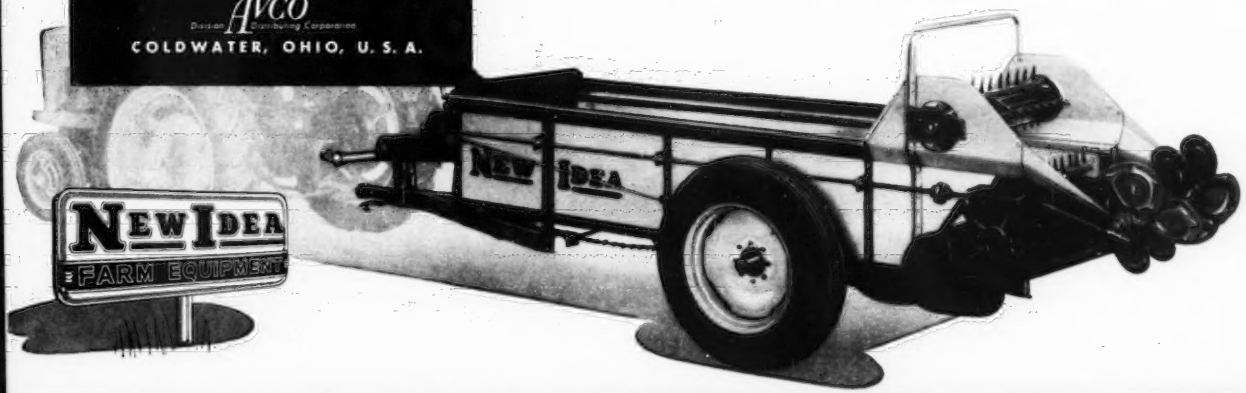
Farmers on small farms prefer the No. 14-A, 65 bushel spreader. It gives them the same original widespread action and wide upper cylinder as its bigger brothers. For use with team or tractor the 75 bu., 4-wheel No. 10-A spreader is available.

...on LARGER Farms

With all the proven advantages of NEW IDEA spreaders plus power take-off, the big 120 bu., No. 15 is the favorite on larger farms. Telescoping power shaft. Bearing support keeps PTO shaft in line and adjusts to various heights.

The NEW IDEA No. 15 PTO spreader provides constant power for wide, even spreading. Has big 120 bushel capacity.

NEW IDEA
FARM EQUIPMENT COMPANY
AVCO Division Distributing Corporation
COLDWATER, OHIO, U. S. A.



"Pressure-Creosoted fence posts last 3 to 5 times longer"

● It's true. Pressure-creosoted fence posts last 3 to 5 times longer than most types of untreated posts. And that long service life means money in the farmer's pocket, not to mention the amount of valuable time and effort he'll save by not having to repair and replace deteriorated *untreated* posts.

In addition to extra-long service life, pressure-creosoted posts offer another very important advantage—they are unharmed by repeated grass fires, sustaining, at the most, only a minor surface char.

For complete information about creosote, write to Koppers Co., Inc., Tar Products Division, Pittsburgh 19, Pennsylvania.

KOPPERS COMPANY, INC., PITTSBURGH 19, PENNSYLVANIA

Tar Products Division

DISTRICT OFFICES:

Woodward, Alabama
Chicago, Illinois, 122 S. Michigan Avenue
New York, N. Y., 430 Park Avenue
Boston, Massachusetts, 250 Stuart Street
Los Angeles, 5, California, 3450 Wilshire Blvd.
Pittsburgh, Pennsylvania, Koppers Building

All Standard Specifications

KOPPERS CREOSOTE

The Performance-Proved Wood Preservative

NEWS SECTION

(Continued on page 742)

ASAE Iowa-Illinois Section Meets November 5

ACCORDING to announcement received from E. G. Rowlett, secretary, Iowa-Illinois Section, ASAE, the first of the 1954-55 series of meetings to be sponsored by the Section will be held at the American Legion Club in East Moline, Ill., Friday evening, November 5. Further information concerning the program of the meeting may be obtained from Section Secretary Rowlett, 2212 E. 12th Street, Davenport, Iowa, or from the ASAE central office in St. Joseph, Michigan.

Pesticide Conference in November

THE 16th annual New York State Insecticide and Fungicide Conference and the 7th annual Pesticide Application Equipment Conference will be held November 9 to 11 in Bibbins Hall, GLF Exchange, Terrace Hill, Ithaca, N. Y. It is suggested that agricultural engineers desiring information on the program, accommodations, etc., for this meeting should address their requests to O. C. French, agricultural engineering department, Cornell University, Ithaca, N. Y.

Grassland Farming Program

THE 1954 annual meeting of the Joint Committee on Grassland Farming will be held November 13 and 14 at the Hotel George Washington, Jacksonville, Fla. A special grassland program will be sponsored by the Joint Committee in collaboration with the Soil Conservation Society of America. This special program will be presented on Sunday, November 14.

Copies of the program and other information concerning the meeting may be obtained from the executive secretary of the Joint Committee, Z. W. Craine, Box 30, Norwich, N. Y.

Report on 33rd NSCBEE Annual Meeting

THE 33rd Annual Meeting of the National Council of State Boards of Engineering Examiners was held at St. Paul, Minn., August 26 to 28, at which ASAE was represented by A. J. Schwantes, a past-president of ASAE, and head of the agricultural engineering division, University of Minnesota. The NSCBEE is made up of representatives of the various state boards, and it regularly makes a practice of inviting representatives of the principal engineering societies to attend its annual meeting. Mr. Schwantes reported as follows on this year's meeting:

Seventeen committees of the organization reported at the meeting, thirteen of which dealt with matters pertaining to registration, such as registration by endorsement, written and oral examinations, engineers-in-training, qualifying experience, uniform laws and procedures, ECPD, and land surveying.

In the matter of examinations for professional engineer registration, there appears to be rather general agreement that the examination should consist of two parts, namely, the fundamental portion which is the same for all candidates and the professional phase. There is some difference of opinion as to the advisability of permitting a candidate to take the second part before he has passed the first part. Total time for the examination is another question being studied; 60 percent of the boards require

(Continued on page 752)

HELP HIM FARM MORE INTENSIVELY

Show him how to plan production with
PORTABLE SPRINKLER IRRIGATION

You and your local farm equipment dealer can help farmers in your county make more intensive use of their land by getting more production from the same acreage. One of the best and surest ways to promote intensive farming is to help farmers plan production with portable sprinkler irrigation. Crops will get off to a good start and mature faster. Growing seasons will be extended with second and third plantings often possible. These are facts you can prove by pointing out the many farms where planned production, with irrigation, has made it possible to improve crop quality and increase yields . . . and at the same time, insure a steady income.

COMBINE YOUR TALENTS

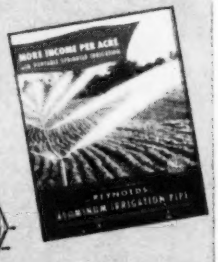
Your agricultural knowledge is a big help in advising farmers on the best sprinkler irrigation practices. With the experience of your local farm equipment dealer who sells Reynolds Aluminum Irrigation Pipe, the two of you can plan a portable sprinkler irrigation system that meets the specific requirements of the farmers you advise.

ACHIEVE YOUR GOAL

Remember—when you work with a dealer who handles Reynolds Aluminum Irrigation Pipe, you work with a man who sells a quality product. Strong, light-weight, rustproof Reynolds Aluminum Irrigation Pipe is the *lifeline* of a reliable portable sprinkler irrigation system. Cooperating, you and the dealer can show farmers in your community how to farm more intensively . . . more profitably on the same acreage . . . with planned production.

REYNOLDS ALUMINUM

Write for your copy of this free booklet on portable sprinkler irrigation systems.



Member of SPRINKLER IRRIGATION ASSOCIATION

Reynolds Metals Company, 2575 South Third Street
Louisville 1, Kentucky

Please send "More Income Per Acre," your new illustrated booklet on the application and advantages of portable sprinkler irrigation.

*Name*_____

*R.F.D. or Street*_____

*Town*_____ *State*_____

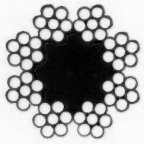
UPSON-WALTON

wire rope and fittings

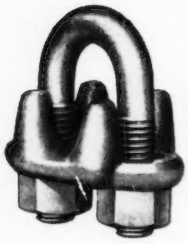
ENGINEERED FOR SAFETY

YOU can fill all farm machinery requirements for wire rope and rope fittings from Upson-Walton —with products especially engineered for safety. Complete catalogs of wire rope and rope fittings available free on request.

Upson-Walton wire rope is available in all standard constructions, and ones particularly suited to farm machinery use. We welcome an opportunity to work with you in selecting the wire rope for your equipment. Our long experience in this field means better service for you.



8 x 7 farm machinery rope



CLIPS

Galvanized drop forged steel (as shown) — Malleable iron enameled or galvanized—For rope diameters: ¼" to 1½".

TURNBUCKLES

Drop forged steel, weldless—self-colored or hot galvanized—with and without stubs, hook, eye, or jaw end fittings—Thread diameters ⅛" to 2".

SHACKLES

Drop forged steel—enameled or hot galvanized—Chain or anchor types — Screw pin or round pin—From ¼" to 2".

THIMBLES

Hot galvanized wrought steel — regular and heavy weights — For rope diameters from 3/16" to 2".

THE UPSON-WALTON COMPANY

12500 ELMWOOD AVENUE • CLEVELAND 11, OHIO

New York • Chicago • Pittsburgh

MANUFACTURERS OF WIRE ROPE, FITTINGS, TACKLE BLOCKS—ESTABLISHED 1871

NEWS OF ASAE MEMBERS

Don H. Malcom, who for several years has been manager of the marketing service department of the Armco Steel Corp., has been named to head a new department recently formed by Armco Drainage & Metal Products, Inc., a subsidiary of Armco Steel Corp., which will direct a major expansion of company activities in the field of prefabricated steel buildings. Called the Steel Buildings Department, it will handle the expansion of Armco's line of buildings and building products and the more complete development of the general market for prefabricated industrial, commercial, and farm buildings. An agricultural engineering graduate of Iowa State College, Mr. Malcom has seen 17 years of service with Armco mainly in the development of steel building construction and marketing, particularly in the agricultural field. He also planned and supervised the market development program of the Porcelain Enamel Institute, in which he worked closely with manufacturers of architectural porcelain enamel.

DON H. MALCOM

Robert A. Norton was recently appointed as agricultural-engineering consultant to the Ingersoll Products Division, Borg-Warner Corp. Previously he was product specification manager of The Oliver Corp., and prior to that he was employed for many years by the U.S. Department of Agriculture and state agricultural experiment stations. For the most part, he has been engaged in investigations of the performance of farm machinery in conservation farming, as a result of which various tillage machines have been developed and modified to improve operation. For a time he was in charge of USDA investigations of weed-control methods and machinery in cooperation with several state agricultural experiment stations.

Mr. Norton is an agricultural engineering graduate from Iowa State College and has a civil engineering degree from the University of Illinois.

Rodney O. Martin, formerly assistant in agricultural engineering, Maine Agricultural Experiment Station, recently accepted appointment as agricultural engineer with the Maine Potato Handling Research Center, Presque Isle, Me., a new cooperative project between the Maine station and the U.S. Department of Agriculture.

Harold S. Stanton recently assumed his new duties as agricultural engineer for the USDA Agricultural Research Service with headquarters at USDA cotton field station at Shafter, Calif. In this capacity, he will replace Herbert F. Miller, Jr., who was recently transferred to the Agricultural Engineering Research Branch headquarters at Beltsville, Md.

Mr. Stanton received a B.S. degree in agricultural engineering at Kansas State College in January, 1950. He served as instructor in the agricultural engineering department at the University of Arkansas from which he received his M.S. degree in agricultural engineering in June, 1953. During his stay at the University of Arkansas, he was instructor in a farm machinery course and was also engaged in cotton mechanization research as a cooperator.

(Continued on page 748)

Harrowing Magic

Dearborn
EQUIPMENT

New Dearborn Adjusto-Flex Disc Harrow

In this year of weather extremes, wise is the farmer who can point to his fields and show you contours, terraces and grassed waterways. For these are effective aids in holding scarce moisture in the soil and in keeping topsoil at home. As more and more farmers turn to conservation farming, the need grows for equipment that will make such farming easier. That's why the new and far advanced Dearborn Adjusto-Flex Disc Harrow is of major interest to those who serve agriculture.

The Dearborn Adjusto-Flex Harrow is raised, lowered and depth-controlled by Ford Tractor hydraulic power. Discs "ride" to and from the field . . . turns at point rows and headlands are made without dirt ridging . . . grassed waterways can be crossed safely and without stopping.

There are many reasons why this new harrow is outstanding for conservation farming. Fast and easy adjustments make for a good discing job under any and all field conditions. Disc gangs are angled separately. A twist of the convenient leveling wheel gives the right cutting action to both front and rear gangs.

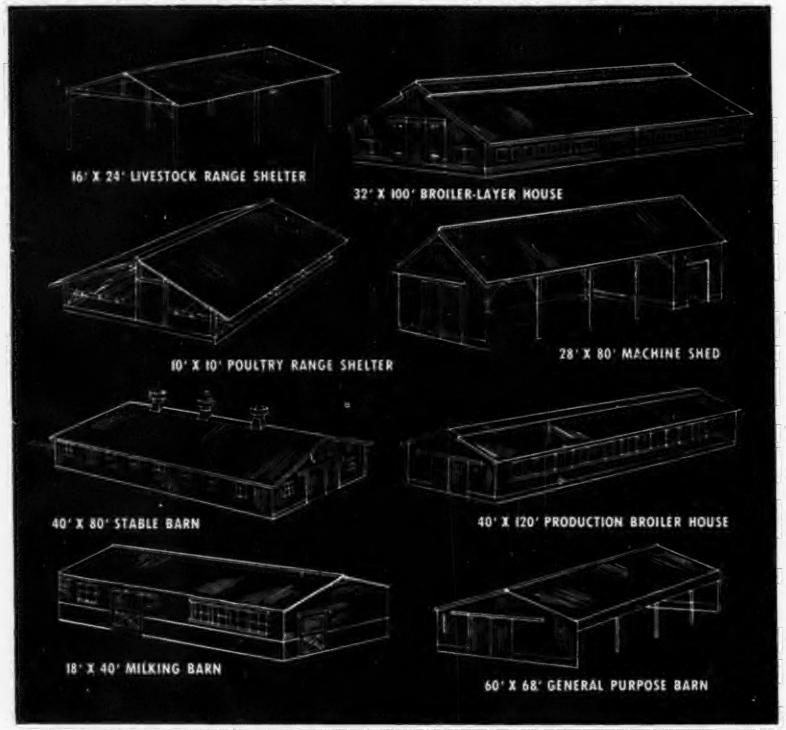
And here's still another advantage: This Dearborn Harrow has a flexible frame that permits disc gangs to follow ground contours—do smooth, uniform work over rolling ground. As if by magic, it does this while maintaining the desired cutting and leveling action.

Matched to the easy-handling Ford Tractor, the Dearborn Adjusto-Flex Disc Harrow becomes a new and valuable aid to good soil management. Here is a new high in discing performance for farmers everywhere.

TRACTOR AND IMPLEMENT DIVISION
FORD MOTOR COMPANY
Birmingham, Michigan

Ford
TRACTOR

Ford Farming GETS MORE DONE ... AT LOWER COST


16' X 24' LIVESTOCK RANGE SHELTER
32' X 100' BROILER-LAYER HOUSE
10' X 10' POULTRY RANGE SHELTER
28' X 80' MACHINE SHED
40' X 80' STABLE BARN
40' X 120' PRODUCTION BROILER HOUSE
18' X 40' MILKING BARN
60' X 68' GENERAL PURPOSE BARN

For Vo-ag Teachers and County Agents:

8 new low-cost farm building plans!

HERE ARE eight brand-new building plans you can effectively use to help farmers improve their construction techniques.

These plans were designed by agricultural engineering specialists. Most feature low-cost pole type construction. Each is a *complete set of blueprints*—including section details, erection instructions, elevations, bill of materials!

With your help, these plans will enable farmers to make the most of all the advantages of Kaiser Aluminum Roofing—in standard sheets, or in the new 48"-wide size!

Among these advantages are light weight with strength, reflection of hot summer sun, retention of winter warmth, long life with no red rust streaks, no rotting, no warping. In addition, Kaiser Aluminum Roofing is economical because it requires less maintenance, is easily applied, never needs paint. Yet it is permanently attractive. The performance tested aluminum roofing material.

Kaiser Aluminum

The Quality Roofing for Better Farm Buildings

ATTACH THIS COUPON TO YOUR LETTERHEAD AND MAIL TODAY!
A sample set of plans will be sent without obligation to agricultural engineers and county agents.

KAISER ALUMINUM & CHEMICAL SALES, INC.
FARM BUILDING PLAN SERVICE
5I029 KAISER BUILDING, OAKLAND 12, CALIFORNIA

Please send a set of the plans to:

NAME _____

ORGANIZATION _____

ADDRESS _____ CITY AND STATE _____

NEWS OF ASAE MEMBERS

(Continued from page 746)

Milo W. Hoisveen, who has been serving as assistant state engineer for North Dakota, on July 1 took over the duties of state engineer as well as chief engineer for the North Dakota State Water Conservation Committee. Duties of the latter include the State's water program, water rights, dam construction, and irrigation, in cooperation with federal agencies dealing with these programs.

Irving J. Pflug was erroneously reported in the September issue as temporarily in the employ of Michigan State College and working for an advance degree in agricultural engineering. Mr. Pflug resigned his position on the agricultural engineering staff of the Massachusetts Agricultural Experiment Station some time ago to accept appointment as associate professor of agricultural engineering at Michigan State College, where he will be specializing on projects in agricultural processing. He obtained his Ph.D. degree in agricultural engineering at the University of Massachusetts, not at Michigan State College.

William G. Harden, who for the past two years has served as research assistant in the agricultural engineering department at Alabama Polytechnic Institute, recently completed requirements for his master's degree in agricultural engineering and has accepted a position as extension agricultural engineer in New Jersey.

Joseph L. Dirnberger has been appointed extension agricultural engineer of the New Mexico Agricultural Extension Service, where he will serve as a specialist in irrigation and drainage. He is a graduate of New Mexico College of Agriculture, with experience in irrigation work with the United Fruit Co. in Central America, and more recently as sales engineer for a supplier of irrigation equipment.

Howard L. Wakeland, who has been serving as instructor in agricultural engineering at the University of Illinois, while working for a master's degree, will continue in that capacity and will also serve as assistant dean of engineering, each on a half-time basis.

Hugh A. Templeton is field service engineer of the agricultural engineering workshops near Hyderabad, Sind, Pakistan, which are under construction by the Sind government. He is working under the Colombo Plan. The project is under an FAO agreement, and the tools and equipment are to come from the United States.

James B. Burford, research engineer in hydraulics, Soil Conservation Service, U.S. Department of Agriculture, who has bene stationed at State College, Miss., is being transferred to Virginia and will be stationed at the agricultural engineering department, Virginia Polytechnic Institute, Blacksburg.

John B. Liljedahl, who has been a member of the agricultural engineering staff of Michigan State College, recently accepted appointment as assistant professor in charge of power and machinery in the agricultural engineering department at Purdue University, Lafayette, Ind.

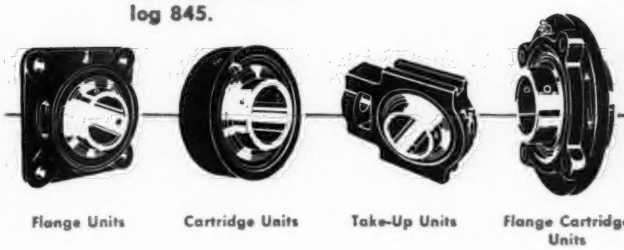
Russell L. Mighell recently resigned as a design engineer of J. I. Case Co. to accept a similar position with Kewanee Machinery and Conveyer Co., Kewanee, Ill.

George H. Newbury, until recently employed as a sales representative of John Deere Plow Co. at Montgomery, Ala., is now located at Ripley, N. Y., where he is operating his own farming business.

the finest mechanized farm implement is no better than the BEARING UNITS transmitting its power!

Write for your FREE copy of *Sealmaster* Catalog 845.

Today's farmer is a combination agriculturalist, engineer and purchasing agent — not only interested in obtaining maximum return from every acre he tills *but* maximum quality and performance from every dollar he spends. The equipment he buys is not a complex mechanism but a piece of machinery whose operation he not only understands but whose maintenance he must personally handle. Experience with SEALMASTER equipped machinery under the most severe field conditions has taught him the importance of quality in every component. SEALMASTER, to the farmer—means long-life, efficient performance and minimum maintenance. You can be sure the bearing unit will be an important check-point in any equipment he buys. Be sure the competitive edge is with *YOU* — there is no substitute for SEALMASTER quality!



Flange Units | Cartridge Units | Take-Up Units | Flange Cartridge Units

SEALMASTER
BALL BEARING UNITS

SEALMASTER BEARINGS

A DIVISION OF STEPHENS - ADAMSON MFG. CO. • 69 RIDGEWAY AVE., AURORA, ILL.

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Anderson, Paul M.—Instructor in agricultural engineering, Pennsylvania State University, State College, Pa.

Arnold, Bruce C.—Product engineer, J. I. Case Co., 625 3rd Ave., Rock Island, Ill.

Bell, Eldridge S. Jr.—Graduate student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) Box 2714, Va. Technical Station

Burnett, Henry H. Jr.—Student of agricultural engineering, University of Florida. (Mail) 218 Village Drive, Elizabethtown, Ky.

Cowsar, John D.—Agricultural engineer, Black, Sivalls & Bryson, Inc., Kansas City, Mo. (Mail) 7416 East 57th St.

Culp, Melvin M.—Head, design section (SCS), USDA. (Mail) 8614 11th Ave., Silver Spring, Md.

Davis, Palmer—Rural service engineer, Alabama Power Co., Winfield, Ala.

Decker, Buck L.—Student engineer, John Deere Waterloo Tractor Works. (Mail) Arard, Okla.

Grace, Thomas T.—Sales manager, James S. Oppenheimer. (Mail) Rua Cel. Oscar Porto 614, Sao Paulo, Brazil

Grube, Harry C.—District sales representative, Metropolitan Edison Co., Boyertown, Pa. (Mail) 240 S. Washington St.

Haddad, Sweilem M.—Irrigation engineer, Michael Baker, Jr., Inc., Baker Bldg., Rochester, Pa.

Harris, Adam H. Jr.—Agricultural engineer, Powell Manufacturing Co., Wilson, N.C.

Hastings, Maurice M.—Irrigation engineer, Colorado A & M College, and Colorado and S&WCRB (ARS), USDA. (Mail) Box 786, Grand Junction, Colo.

Higgins, Paul N.—Sales manager, Food Machinery and Chemical Corp., Box 1608, Moses Lake, Wash.

Hill, James J.—Agricultural engineer, Rear's Farm Service. (Mail) RR 1, Junction City, Ore.

Johnston, Grant M.—Design engineer, International Harvester Co., Sherman Ave., N., Hamilton, Ont., Canada

Leary, R. C.—Assistant service manager, Tractor & Implement Div., Ford Motor Co., 2500 E. Maple Rd., Birmingham, Mich.

Luthin, James N.—Assistant professor of irrigation, University of California, Davis, Calif.

Miller, Thurman G. Jr.—Field representative, N. C. Rural Electrification Authority, PO Box 630, Raleigh, N. C.

Mullins, James A.—Junior agricultural engineer, USDA, Edisto Experiment Station, Blackville, S. C.

Nichols, John B.—2nd Lt., USAF. (Mail) RR 2, Minatare, Nebr.

Norris, James W.—Agricultural engineer (SCS), USDA. (Mail) Box 271, Ocala, Fla.

Phillips, Willard R.—Manager, quality control department, Tractor & Implement Div., Ford Motor Co. (Mail) 13103 Borgman, Huntington Woods, Mich.

Reeves, William D. M.—Pump irrigation engineer, Foreign Operations Administration, USAOM-FOA, APO 928, c/o Postmaster, San Francisco, Calif.

Rempel, Carl L.—Engineer (SCS), USDA, Quincy, Wash. (Mail) Box 1018

Shaw, Mark D.—Instructor in agricultural engineering, Pennsylvania State University, State College, Pa.

Sparks, Jack L.—Irrigation engineer, Michael Baker, Jr., Inc. (Mail) 170 Neville Road, Dawson Ridge Plan, Beaver, Pa.

Thomas, Harry D.—Electrification advisor, Four County Electric Membership Corp., Burgaw, N. C. (Mail) PO Box 323

Travis, Dean H. Jr.—Irrigation specialist, Suburban Farm Service Co., Wilson, N.C. (Mail) 1008 Bynum St.

Walker, John N.—Instructor in agricultural engineering extension, Pennsylvania State University, State College, Pa.

Walte, Charles Jr.—Director of Farm Institute, Reynolds Metals Co., 2000 S. Ninth St., Louisville, Ky.

Weasler, A. V.—President and general manager, Weasler Engineering & Mfg. Co., West Bend, Wis. (Mail) PO Box 275

Wiggin, Merlon E.—Agricultural engineer (SCS), USDA, Presque Isle, Me. (Mail) 58 Dyer St.

Transfer of Membership Grade

Wolf, Charles E.—Farm service representative, New York State Electric & Gas Corp. (Mail) W. Church St., Eden, N. Y. (Affiliate to Associate Member)

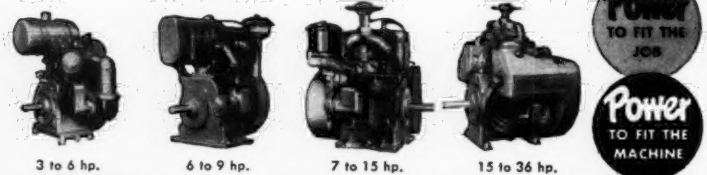
Dowling, Saint Elmo—Agricultural engineer, Moore Dry Kiln Co., Jacksonville, Fla. (Mail) 1946 Leonid Road. (Associate Member to Member)

In 1953 a leading Design trade magazine conducted a survey among 1902 manufacturing plants on the use of Internal Combustion Engines of less than 60 hp., as power components in equipment made for resale.

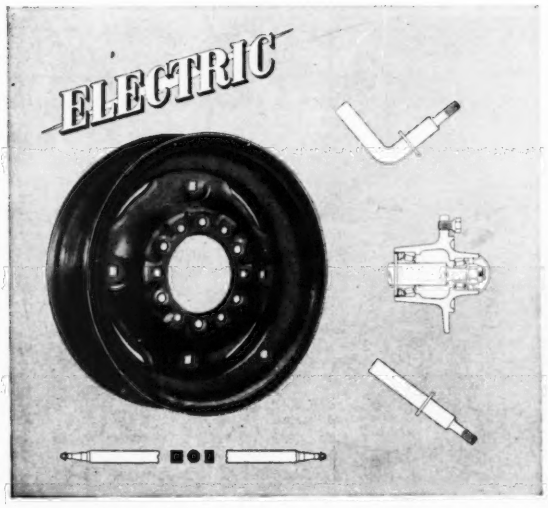
Projected returns from 42.6% of plants contacted showed an estimated 678 plants using engines in the stated category, representing total engine purchases of 2,727,216.

Answering the question: "Who makes the Internal Combustion Engines you Use?" . . . Wisconsin Motor Corporation received 132 mentions, as against 105 for the second place builder, 56 for No. 3, 51 for No. 4 — in a list of 41 classified engine manufacturers.

This outstanding preference for Wisconsin Heavy-Duty Air-Cooled Engines (although limited to a power range of 3 to 36 hp. in a broad survey classification including ALL engines below 60 hp.) provides tangible evidence that "WISCONSIN" rates first among men who know engines best. We'd like to count you among them.



WISCONSIN MOTOR CORPORATION
World's Largest Builders of Heavy-Duty Air-Cooled Engines
MILWAUKEE 46, WISCONSIN



A Wheel for Every Job!

Our engineers will recommend the most efficient and economical wheel and axle assembly for your unit. We invite your inquiries.

WRITE US FOR CATALOG
ELECTRIC WHEEL CO.
2806 SPRUCE, QUINCY, ILLINOIS

the BADGE of him who BELONGS

DESPITE the *presumption* it sets up, mere membership in the American Society of Agricultural Engineers is no *proof* of a man's high rank in technical talent. It does prove that he has met certain minimum requirements and has earned the esteem of colleagues who sponsored his application for membership.

But the Society emblem is *evidence* that native talent, be it great or small, is enriched by fraternity with the personalities whose minds fuse to form the pattern of progress in the methods and mechanics of agriculture. The wearer of the emblem waits not for the debut of an idea, but is present at its birth and helps to guide its growth.

Be you novice or veteran, your membership in the organized profession adds something to your efficiency, your vision, your influence as an individual engineer. The Society symbol on your lapel is token that you "belong". Wear it.

STYLES AND PRICES OF ASAE EMBLEMS

With blue ground for Fellows, Members, and Associate Members — furnished either in pin with safety clasp or lapel button — $3.50 each.

With red ground for Affiliates — furnished only in pin with safety clasp — $3.50 each.

Send orders to ASAE, St. Joseph, Michigan.

$700 saved . . .

more efficiency gained

with

courtesy IOWA MFG. CO.

That's the experience of the IOWA MFG. CO., manufacturers of this super-tandem crushing plant which employs a 1¼" STOW power drive shaft, operating at 800 RPM. A centrifugal clutch relieves sudden starting loads. Use of the flexible shaft as shown permits a swing of up to 90 degrees either side of the center line.

This is another fine example proving the efficiency, the practicability of STOW flexible shafting.

Why not consult with STOW engineers on your next power transmission problem. You'll find that Stow flexible shafting can really do a job for you!

***Write today** for this free bulletin 525 and Torque Calculator, containing complete data on STOW flexible shafting. No obligation, of course.*

STOW MANUFACTURING CO.
39 SHEAR ST. BINGHAMTON, N. Y.

UNITCAST Customers Service starts *before* you buy!

It's a fact! Unitcast's service to the customer starts *before* the final prints are drawn, and continues until you're satisfied! Coordinated effort between Unitcast engineers and the customer . . from the design to the finished casting, provides better results all around.

Briefly, this is our side of the story. Check the following outline of *Unitcast's Service facilities* . . see if you're getting all the attention you deserve!

★ **DESIGNING** Service . . analyzes existing designs from the blueprint. Submits full, comprehensive report to the customers engineering facilities. Aids the customer in arriving at a conclusion with the foundry for the best possible design, from both castable and usable views.

★ **ESTIMATING** Service . . provides accurate cost figures with every necessary step itemized. Submitted after mutual design problems are solved and quantity and initial delivery requirements are established.

★ **PRE-PRODUCTION** Service . . includes pattern expediting and construction in conformity with production requirements. to realize economies wherever plausible. Includes sample casting presentation in minimum time for formal approval.

★ **SCHEDULING** Service . . coordinates production with customers requirements. Includes accumulation service for full truck load, and methods such as palletizing for faster handling. All shipping facilities are available directly at the foundries.

★ **SPECIAL** Service . . available after consultation. Includes close tolerance castings, special heat treating, intensified inspection of critical areas, and other finishing requirements not considered standard procedure.

★ **FOLLOW-UP** Service . . carried out periodically during production and delivery, aids both foundry and customer production. Design revisions, greater efficiency, revised schedules, etc., stem from this customer service.

UNITCAST CORPORATION • Toledo 9, Ohio

In Canada: CANADIAN-UNITCAST STEEL, LTD., Sherbrooke, Quebec

Unitcast QUALITY STEEL CASTINGS

NEWS SECTION

(Continued from page 744)

two days while most of the remainder use less time.

Practice with regard to oral or written examinations varies in different states. Some feel that no part of the examination should be oral, whereas others believe that it is extremely important that some parts should be oral. Another point of difference is the question of permitting the use of books in the written examination.

The manner in which these and similar questions were considered by the Council gives the impression that examinations and registration in most states are being well handled. It appears to be common practice for examining boards to maintain close relationship with faculties of engineering colleges, and it would seem well for agricultural engineering department faculties to extend their fullest cooperation to state boards whether agricultural engineers as such are registered or not in their states.

The Scientific Manpower Situation

IT TOOK a technological war of world proportions to suggest that the problem of scientific and engineering manpower might profitably be studied; and the threat of another such war to initiate action. Inevitably government agencies took the lead in analyzing those aspects of the problem that required immediate attention, but discontinuity of effort and uncertainty of purpose characterized official efforts and nullified any constructive or lasting result.

In response to appeals from the NSRB (National Security Resources Board) committee under the chairmanship of Charles A. Thomas, the Engineers Joint Council created the Engineering Manpower Commission in 1950, and in 1951 the American Chemical Society appointed a committee on manpower. The chemists were convinced from the start that most manpower problems are common to all fields of science and that a single agency acting in behalf of all the major groups would accomplish much more than separate committees working without coordination. This conviction was shared by the organizations in the other disciplines, and in March, 1953, representatives of the AAAS, ACS, AIBS, AGI, AIP, APA, FASEB, and PCM joined forces to incorporate the Scientific Manpower Commission in the District of Columbia.

With a dozen different government departments and agencies and an equal number of private organizations working on one phase or another of the specialized manpower problem, the Commission's first task was to study all activities in the field and to establish working relations that would eliminate duplication of labor yet assure that a comprehensive job would be done. Progress toward this goal was accelerated when Arthur S. Flemming, director of the Office of Defense Mobilization, appointed Howard A. Meyerhoff, the Commission's 1953 president, to membership on the ODM Committee on Specialized Personnel, and when the Engineering and Scientific Manpower Commissions agreed to merge certain of their activities and to divide the labor on others.

In such highly specialized fields as the scientific disciplines, recruitment, training, and utilization are successive but integrated problems. Superimposed on the troublesome dilemma of an inadequate supply of scientists to meet civilian demands was their

(Continued on page 754)

GEARS

of every description—made to your specifications

The gears you buy from E. B. Sewall are made by men who are fussy about specifications. They've got the finest equipment and know how to use it. If you specify .0002" tolerance, you get it—at each tooth on every gear we ship. We're in a brand new plant, equipped to handle your gear requirements. Send specifications and quantity for our quotation.

Your inquiry will be answered promptly

SEWALL

E. B. Sewall Mfg. Co., 702 Glendale St., St. Paul 14, Minn.

Who Should Join ASAE

If any one of the following descriptions covers your present work:

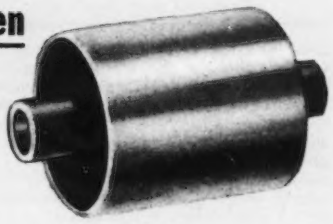
- Development, design, and application of farm tractors and implements and their components
- Design and improvement of farm buildings
- Engineered improvements for soil and water conservation and use
- Creating applications for electricity in farm practice and living—

then you can derive much benefit from membership in ASAE, and the Society cordially invites you to make application. For further information write

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

St. Joseph, Michigan

Farm-Proven Silentbloc Bearings



Never Require Lubrication!

These unique rubber-in-metal bearings correct misalignment, reduce noise, cushion shock, and handle oscillating motion *without lubrication of any kind.* In addition, they eliminate metal-to-metal wear and provide long trouble-free operation.

General Silentbloc bearings and bushings are used on agricultural machinery wherever motion is a problem. Special Silentbloc units can also be designed and manufactured to meet your particular need. Our service also covers extruded plastics and rubber, molded rubber and fiberglas, metal stampings, rubber-to-metal. Write for the full story today.

"From Plans to Products in Plastics and Rubber"

THE GENERAL TIRE

Industrial Products Division

WABASH INDIANA

The General Tire & Rubber Company
Industrial Products Division
Wabash, Indiana

☐ Send booklet on Silentbloc products (4240)
☐ Send booklet on complete products and services (4252)
☐ Have your representative contact us.

Company_____ Name_____

City_____ Street_____ State_____

AE—10-54

Scientific Manpower Situation

(Continued from page 752)

liability for military service. Despite the excellent work of the Trytten Committees, the treatment accorded graduate students from May, 1953, until June, 1954, became completely irrational, and Selective Service announced as a policy its intention to induct graduate assistants without regard to the status of their graduate work. Graduate schools promptly supplied the Commission with facts and figures on arbitrary and ill-timed inductions of students in midcareer, and the Commission's findings were placed before the Office of Defense Mobilization. Action was soon taken, and, unless there is complete disregard of the permissive provisions of the law, thus jeopardizing the technological strength of the nation, students and university departments will no longer be harassed by the uncertanties of badly timed and arbitrary reclassifications and inductions.

The Commission has also insisted on the adoption of more rational handling of occupational deferments, and, after a year in which it looked as if the policy was to draft all scientists, without regard to their irreplaceability in critical occupations, the Selective Service System should soon be directed to adhere to the intent of the deferment provisions in the Selective Service law. In 1955 it will be necessary for Congress to pass new legislation, in which it is hoped basic principles will be spelled out in sufficient detail to place them beyond dispute, and in which the chaotic reservist situation will be put in order. The Commission has been assured that its views will be sought when the prospective bills come up for consideration.

There would be little point in all this activity on the proper utilization of scientists for national security if there were not a shortage, at least in certain fields. The register of scientific personnel that is being prepared for the National Science Foundation will provide a check on the available supply, and the Office of Education's annual survey of college and university registrations and of degrees granted is a reliable tally of the number of new scientists and engineers that are added to the manpower pool each year. Very little, however, has been done to determine the demand and its relation to the supply. Unwilling to accept unsupported generalizations about current shortages, the Scientific Manpower Commission has undertaken its own survey. A comprehensive study of industry's immediate requirements for scientists in each major field has been completed, and the results will soon be available. A comparable survey of demand for fiscal year 1954-55 in government agencies is in progress, and this will be followed by a study of requirements for teaching personnel during academic year 1954-55. Even reliable statistics such as are being assembled must be carefully interpreted before they can be properly used in the formulation of national policy, but until now anyone was free to propound an opinion or to propose a policy affecting the nation's scientific future and its security without being seriously hampered by facts.

Although there is always a shortage of high-caliber scientists, programs of recruitment should bear some rational relationship to prospective demand, and the results of the SMC surveys should be guides for action in each field of science. In preparation for service in this vital facet of the manpower problem, the Commission has compiled a bibliography of literature on career guidance and has assembled a file of material in current use among student counselors. Some disciplines have excellent material (two have virtually none) to place in the hands of interested young people.

Pamphlets, however, are no substitute for the inspiration that good teachers and good counselors can provide, and for this reason SMC has joined with the Engineering Manpower Commission to face the most acute shortage of all, namely, that of high school teachers of science. Working with the National Science Teachers Association, the Future Scientists of America, the AAAS Cooperative Committee on the Teaching of Science and Mathematics, the Academy Conference of the AAAS, the Thomas Alva Edison Foundation, and the Educational Council of the National Association of Manufacturers, it is now seeking the cooperation of its sponsoring agencies and their affiliates in a nationwide effort to resuscitate science where most young men and women have their first introduction to it. The Commission is also anticipating the time—a scant four years ahead—when the colleges will feel the pinch that has just gripped the high schools.

Science and technology are abstract terms that acquire substance only through people—men and women with the right temperament and with minds disciplined by prolonged training. Like any resource, the supply is limited, though renewable. Yet we have known less about it than about the size of our coal reserves or of our wheat crop. In fifteen months of operation, the Scientific Manpower Commission has begun to perceive the many facets of the manpower problem and to see how some of them may be resolved. The degree of success achieved

(Continued on page 758)

KOHLER ENGINES

4-CYCLE
AIR-COOLED

K90 3.6 H.P.
K160 6.6 H.P.
K330 11.8 H.P.
K660 26.8 H.P.

Kohler Engines are engineered and manufactured to the high standards which have made the Kohler mark known for quality the world over.

Power for garden tractors, pumps, sprayers, snow removal equipment, grain elevators, hoists, portable saws, concrete mixers, compressors, industrial lift trucks.

Write for information

Kohler Co., Kohler, Wisconsin
Established 1873

KOHLER OF KOHLER

PLUMBING FIXTURES • HEATING EQUIPMENT • ELECTRIC PLANTS
AIR-COOLED ENGINES • PRECISION CONTROLS

RAIN BIRDS® Set the pace for Performance

More farmers use Rain Birds than any other sprinklers. Why? Rain Birds' simplicity of design and unexcelled performance answer today's irrigation requirements. For your protection look for the name "RAIN BIRD" on the sprinklers you buy.

Be sure the sprinkling system you get meets American Society of Agricultural Engineers standards and fits your needs exactly.

Our research and planning department is at your service. Consult us today without obligation.

Member Sprinkler Irrigation Ass'n.

NATIONAL RAIN BIRD SALES & ENGINEERING CORP.
AZUSA, CALIFORNIA

RAINY SPRINKLER SALES
609 WEST LAKE ST., PEORIA 5, ILLINOIS

A Handsome, Permanent Binder for AGRICULTURAL ENGINEERING

One copy **$2.80**
Two or more
$2.40 each

The ONLY binder that opens flat as a bound book! Made of durable imitation leather, nicely stamped on front cover and backbone, with name of journal and year and volume number, it will preserve your journals permanently. Each cover holds 12 issues (one volume). Do your own binding at home in a few minutes. Instructions easy to follow. Mail coupon for full information, or binder on 10-day free trial.

---------- MAIL COUPON TODAY ----------

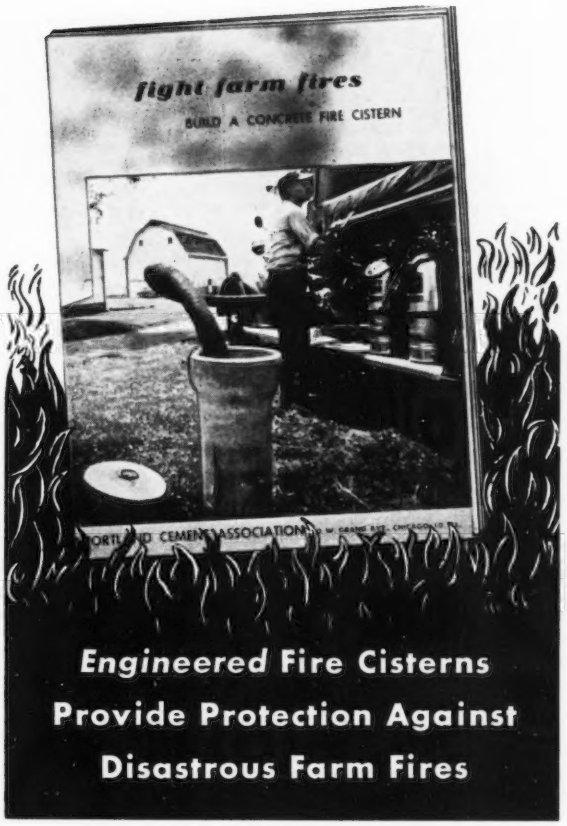
SUCKERT LOOSE-LEAF COVER CO.
234 West Larned St., Detroit, Mich.

Mail postpaid.....binders for Agricultural Engineering for years.....
Will remit in 10 days or return binders collect.

Name.....

Address.....

City.....State.....



Engineered Fire Cisterns Provide Protection Against Disastrous Farm Fires

Every 24 hours fire strikes 100 farm families, leaves 9 persons dead and destroys $250,000 worth of farm property.

Agricultural engineers can help reduce this heavy loss by (1) encouraging the use of fire-safe concrete construction and (2) designing concrete fire cisterns that provide an abundant supply of water for fighting fires.

An underground concrete fire cistern will store water economically and efficiently. Through cooperation with rural builders or groups of farmers it is possible to make multiple use of the same set of forms. This simplifies construction, saves money and provides each farmer with priceless fire protection.

Designing underground cisterns for protection against fires is another example of the agricultural engineer's service to America's farmers. For helpful design data write for the booklet illustrated above. It is free but is distributed only in the United States and Canada.

PORTLAND CEMENT ASSOCIATION
Dept. 10-1, 33 W. Grand Ave., Chicago 10, Ill.
A national organization to improve and extend the uses of portland cement and concrete . . . through scientific research and engineering field work

NEW PRODUCTS CATALOGS

Wheel-Type Disk Harrow

John Deere, Moline, Ill., announces a new wheel-type disk harrow, the model RW. The backbone of this disk harrow is of heavy pipe, resistant to stress and strain. Heavy channel steel main frame members are welded to the backbone, and the disk gangs in turn are bolted to the heavy-duty frame members at a fixed angle. Other features of the implement are tapered wheel bearings and heavy-duty, heat-treated, cross-rolled disk blades. The harrow is made in 7, 8, 9, 10 and 14-foot sizes, with 16 or 18-inch disks.

A hand screw, the only adjustment on the harrow, raises or lowers the hitch to the tractor drawbar, and the implement can be raised, lowered, or adjusted by any tractor hydraulic cylinder that conforms to ASAE-SAE standards. It can be raised and locked

in transport position so the hydraulic cylinder can be removed for other use.

Glossary of Terms for Iron Castings

International Nickel Co., 67 Wall St., New York 5, N. Y., will send on request to interested readers a copy of its 36-page booklet entitled "Glossary of Terms for Producers and Users of Iron Castings," which explains over 150 technical terms that are used in common between suppliers and users of ferrous and non-ferrous castings. It is offered to increase the mutual understanding that promotes greater accord in working out the procurement of satisfactory and improved castings. Also, it should prove useful to the designer, machinist and purchaser of castings as well as to the man in the foundry.

Idea File on Metal Shapes

Van Huffel Tube Corp., Warren, Ohio, will, on request of interested readers, send one of its idea file folders containing idea sheets showing the many applications for Van Huffel cold-formed metal shapes and tubing the company believes will be useful to manufacturers of the farm equipment industry. Engineers confronted with ideas for product development or improvement, especially where cold-formed metal shapes and tubing offer opportunities for simplifying design and cutting production costs, will find this idea file folder useful.

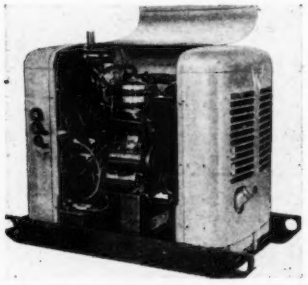
New Model Sprinklers

National Rain Bird Sales & Engineering Corp., Azusa, Calif., has introduced two new model irrigation sprinklers. One of these, the No. 30, is an innovation in two-nozzle sprinklers. Of the same construction as the No. 30 W announce six months ago, it includes the addition of a spreader nozzle, increasing sprinkler efficiency and assuring satisfactory service under extreme irrigation

conditions. A companion model to this sprinkler is the No. 35 which operates on a part or full circle and is recommended for use on lateral ends to keep water off roads during irrigation periods. It is constructed with fewer moving parts than the previous model, No. 45, and offers advantage of more advanced irrigation techniques. Both sprinklers use the ¾-inch, No. 40 original standard and wearproof bearings, thus reducing the number of repair parts to be stocked.

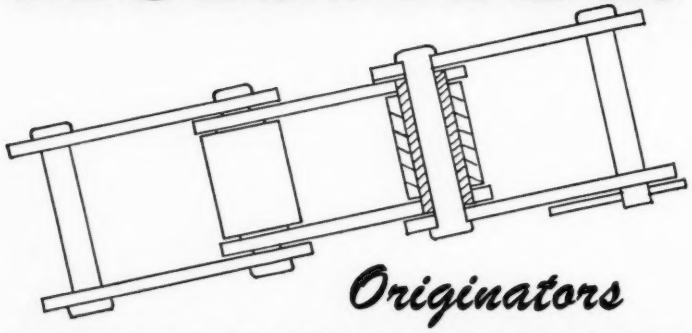
New Engine Power Unit

Willys Motors, Inc., Industrial Engine Dept., Toledo, Ohio, announces a new power unit, in which any of the company's four industrial engines can be installed in a completely operable engine package, which



is equipped with radiator, gas tank, air cleaner, complete electrical equipment and governor. The enclosure is a heavy-gauge, steel housing designed for rugged duty and appearance. The unit is mounted on reinforced skids. The Company's models L-4, F-4, L-6 and F-6 industrial engines can be assembled into this unit.

REDUCE COSTLY BREAKDOWNS WITH CHAINS, INC.



Originators

OF HIGH QUALITY LOW COST IMPLEMENT ROLLER CHAIN

Chains, Incorporated is supplying complete quality chain drives for combines, corn pickers, spreaders and other applications in the agricultural field as well as the industrial field. For the best in roller chain at attractive prices

WRITE FOR COMPLETE DETAILS

CHAINS, INC.

13943 PARK AVENUE **DOLTON, ILLINOIS**

A.B.C.–FOR 40 YEARS GUARDIAN OF CIRCULATION INTEGRITY

How Advertisers Measure Circulation Value

You know the audience you're getting when you invest advertising funds with us. We're members of the Audit Bureau of Circulations – our circulation is net paid and A. B. C.-audited.

The Bureau is a voluntary, nonprofit association founded forty years ago by advertisers, advertising agencies and publishers, to bring order out of circulation chaos. It sets standards for net paid circulation, verifies circulation records by field audit and issues A.B.C. reports.

Our A. B. C. report accurately states and analyzes our circulation; tells exactly how much we have, where it goes, how we obtain it. *Write us for your copy*. It will show you where and to how many readers we carry your sales message.

We're proud to be among the 3575 members who have helped make A.B.C facts your basic measure of advertising value.

AGRICULTURAL ENGINEERING

A.B.C.—40 YEARS OF IMPARTIAL FACT-FINDING & FACT-REPORTING

AGRICULTURAL ENGINEERS YEARBOOK

Reaches

All members of the American Society of Agricultural Engineers *including*

1. Chief engineers, design engineers, and others who specify the designs, components, materials, etc., built into farm tractors and machines.
2. Agricultural engineers in state and federal employ who advise farmers in the selection and application of farm equipment of all kinds.
3. Engineers in soil and water conservation who specify methods, machines, and equipment in irrigation, drainage, and erosion control operations.
4. Agricultural engineers who spearhead advances in functional and structural design of farm-housing and crop-storage buildings.
5. Engineers who have pioneered the engineering applications of electricity on 90 per cent of American farms.

CONTENTS

The 1955 AGRICULTURAL ENGINEERS YEARBOOK will contain items of information which agricultural engineers frequently need to consult, the more important of which are:

- ASAE-approved standards, recommendations, codes, and data.
- Directory of manufacturers (1) of components, materials, etc., specified in designs for farm machines, structures, and other equipment, and (2) of complete machine and structural units used in farming and allied operations.
- Alphabetical and geographical directory of ASAE members.
- Roster of ASAE officers, divisions, sections, and committees, and other organizational information.

AGRICULTURAL ENGINEERS YEARBOOK will be found on the desk of every ASAE member where it serves as a ready reference throughout the year.

Reserve space NOW for the 1955 edition.

Published annually by

American Society of Agricultural Engineers

505 PLEASANT STREET, ST. JOSEPH, MICH.

Also publishers of AGRICULTURAL ENGINEERING

PERSONNEL SERVICE BULLETIN

NOTE: In this bulletin the following listings current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated.

POSITIONS OPEN—APRIL—O-90-613, 98-614, 106-615. MAY—O-155-623, 108-624, 162-625, 173-626. JUNE—O-180-627, 181-628, 197-629, 198-630, 182-631. JULY—O-204-633, 205-634, 207-635, 209-636, 208-637, 219-638, 222-639, 223-640, 231-642, 232-643. AUGUST—O-242-644, 248-645, 250-647, 251-648, 244-649. SEPTEMBER — O-276-650, 262-651, 286-652, 288-653, 293-654, 300-655.

POSITIONS WANTED—APRIL—W-125-126, 107-127. MAY—W-122-128, 146-129. JUNE—W-115-131, 164-133, 169-134, 179-136, 199-137. JULY —W-177-138, 224-141. AUGUST—W-237-142, 252-143, 265-144. SEPTEMBER — W-283-145, 246-147, 260-148, 266-149, 294-150, 299-151.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER, assistant or associate professor rating, to take charge of agricultural engineering teaching, research, and extension in an eastern state university. Age 25-35. MS deg in agricultural engineering, or equivalent. Experience in teaching and research or extension and research. Able to meet and work with people. Aggressive and willing to work more than a 40-hour week to build up agricultural engineering program. Excellent opportunity to develop agricultural engineering to the point where it can become a separate department. No salary or rank schedules to hold down a good man. Usual retirement, social security, hospitalization and insurance benefits. Salary open. O-326-656

RESEARCH ASSISTANT in agricultural engineering for work on mechanization of dairy and poultry farms, in a northeastern land grant university. Age, under 35. BS deg in agricultural or mechanical engineering. MS deg in agricultural engineering desirable. Farm background and some design or test experience desirable. Interest in research and ability to write up projects and results. Above average opportunity in expanding research program. Excellent retirement system. Location in rural section close to larger cities in Northeast. Salary $4380, or more if qualifications warrant, for 11 mo. O-332-657

AGRICULTURAL ENGINEERS (4) for product test work with a large farm equipment manufacturer in the Midwest. Work includes writing test plans, supervising and conducting field tests, observing test results and writing reports on tests of tractors or implements. Age 30-45. BS deg in agricultural or mechanical engineering. Farm background and four to six years experience in farm equipment field. Tractor or implement design experience desirable. Willing to travel. Able to train and supervise younger, less experienced personnel. Men with mature, sound judgment on the function and performance of experimental farm equipment are desired. Good opportunity for advancement in expanding organization. Salary, $500 to $550 per mo, depending on qualifications. O-321-658

AGRICULTURAL ENGINEER to develop and carry on an extension program in the use of farm machinery, principally in cotton production, in a southwestern state. Age 28 or over. BS deg in agricultural or mechanical engineering, preferably from a land grant institution. Experience in mechanized farming desirable, preferably since graduation. Must like and be able to work with rural people. Good opportunity for advancement. Salary $5000. O-327-659

AGRICULTURAL ENGINEER to assist manager of agricultural engineering with a name brand vegetable canner in the Upper Midwest. Work will include assisting with design and development on tillage, fertilizing, planting and harvesting equipment; and with maintenance, improvement, management and operation of fleets of field machines. Age about 24-28. BS deg or higher in agricultural or mechanical engineering. Practical experience in design and development, servicing or fleet operations desirable. Must be able to work with people. Excellent opportunity for well-qualified man interested in application of engineering principles to agricultural production operations. Salary $366 to $422 to start. O-353-660.

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER for extension, teaching, research, sales, service, or writing in rural electric field, with industry or public service, preferably in East or Midwest. Will travel. Single. Age 30. Vision corrected. BS deg in agricultural engineering, 1949, Pennsylvania State College. MS deg in agricultural engineering 1951, Michigan State College. Farm background. Design and test with manufacturer of farm equipment, 6 mo. Graduate teaching assistant in rural electrification, 15 mo. Test engineering program with manufacturer of farm electrical equipment, 15 mo. Development, design and test of military electronic equipment (radar) with electrical manufacturer, 23 mo. Weather, 18 mo, and electronics school, 4 mo, in Air Force during military service. Available on 2 weeks notice. Salary open. W-296-152

ENGINEER FOR TEACHING, sales, or service in power and machinery, with manufacturer or distributor, in USA, Latin America, or Scandinavia. Able to use Spanish language. Willing to travel up to 8 mo per year. Resident of USA. Married. Age 30. No disability. Technical training at Gothenburg College 1943 and Technical Institute of Gothenburg, 1945, mechanical engineering. Military service in Sweden, one year as mechanic in motor pool. Sales engineer and regional technical supervisor in Latin America, 5½ yr, with U.S. manufacturer of farm equipment. Partner in farm in Panama. Available now. Salary $425 per mo. W-330-153

HORTICULTURAL and vegetable crop specialist, for extension, teaching, or research with college or experiment station, anywhere in USA. Married. BS deg in agriculture, major in horticulture, 1949, Rutgers University. MS deg in agriculture, major in vegetable crops, Michigan State College, 1950. War noncommissioned service in Army Air Force, 3 yr. Assistant county agricultural agent, present position, 15 mo. Available now. Salary $5000. W-340-154

AGRICULTURAL ENGINEER for farm management, consulting, or sales and service work with private industry in South or Southeast. Age 30. Married. BSA degree University of Florida, 1947, major in agricultural engineering. Farm background. Three years service commissioned officer, U.S. Navy. Two years teaching experience; one year land appraisal; one year farm equipment sales and service; two years present position as agronomist for private industrial organization. Willing to do limited travel. Available 30 days notice. Salary open, depending on other conditions of employment. W-365-155

AGRICULTURAL ENGINEER for design and development with manufacturer of farm equipment, preferably in the Northeast. Married. Age 25. No disability. BS deg in agricultural engineering, 1952, University of Vermont. Farm background. One summer as draftsman. Design with farm equipment manufacturer 6 mo, until called to duty in Army. Army experience includes 24-week electronics school, 18-week Ordnance Guided Missile Electronic Component School course, and teaching in the latter since that time. Discharge due January 1955. Available February 1955. Salary open. W-349-156

Scientific Manpower Situation

(Continued from page 754)

will be directly proportional to the support and cooperation given not only by its sponsors, but by scientists themselves. It is the profession's problems, rather than the Commission's that must be faced.

* * *

The Scientific Manpower Commission on August 31 elected Truman E. Hienton, head, farm electrification section, agricultural engineering research branch (ARS), U.S. Department of Agriculture, and Marvel L. Baker, associate director, Nebraska Agricultural Experiment Station, as the new members of the Commission representing the field of agriculture. This increases SMC membership to 18, representing 9 major fields of scientific activity vital to the nation's defense, economy, and welfare.

"7,125 men and women signed up to join those already saving for their financial security..."

GEORGE H. COPPERS
President,
National Biscuit Company

"There is no greater honor than partnership in an enterprise as important to a nation as the Payroll Savings Plan for United States Savings Bonds. We view our recent person-to-person canvass of employees in behalf of Bonds as practical patriotism. It supports our Government's efforts to stabilize the value of the dollar. The campaign also benefited our employees. 7,125 men and women signed up to join those already saving for their financial security in this easy, automatic way."

The Payroll Savings Plan is the backbone of Series E Bond Sales. 8,500,000 employees in more than 45,000 companies invest more than $160,000,000 in Savings Bonds *every* month.

The person-to-person canvass is the keystone of The Payroll Savings Plan. In company after company person-to-person canvasses *conducted* by *employees* have increased participation to 60%, 70%—even 90% plus.

Why don't *you* conduct a person-to-person canvass in *your* company? Here are two, simple steps:

- Tell the Savings Bond Division, U.S. Treasury Department, Washington, D.C., you want to conduct a person-to-person canvass, they will show you how easy it is to install the plan.
- Over *your* signature tell your men and women you are 100% behind the Payroll Savings Plan because it enables them to build personal security . . . it is a check on inflation and helps to stabilize the dollar . . . it has set up a reservoir of reserve purchasing power—over $37.5 billion—the cash value of Savings Bonds held by individuals at the end of July, 1954. The greatest reserve of purchasing power this or any other country has ever had.

Your phone call, telegram or letter to Savings Bond Division, U.S. Treasury Department, Washington 25, D.C., will bring prompt co-operation from your State Savings Bond Director. Act today.

The United States Government does not pay for this advertising. The Treasury Department thanks, for their patriotic donation, the Advertising Council and

AGRICULTURAL ENGINEERING

Index to Advertisers

Aeroquip Corp.	692
Allis-Chalmers Mfg. Co.	739
Armco Steel Corp.	701
Audit Bureau of Circulations	757
Bearings Co. of America	684
Bendix Aviation Corp.	693
Blood Brothers Machine Co.	689
J. I. Case Co.	2nd cover
Chains, Inc.	756
Char-Lynn Co.	760
Cleveland Welding Co.	696
Crucible Steel Co. of America	700
Electric Wheel Co.	751
Ethyl Corp.	686
Ford Motor Co., Tractor & Implement Div.	747
General Tire & Rubber Co., Industrial Products Div.	753
Great Lakes Steel Corp., Stran-Steel Div.	702
Hyatt Bearings Div., General Motors Corp.	704
International Harvester Co.	690
International Nickel Co.	691
Kaiser Aluminum & Chemical Sales, Inc.	748
Kohler Co.	754
Koppers Co., Tar Products Div.	744
Link-Belt Co.	685
Mechanics Universal Joint Div., Borg-Warner Corp.	681
National Rain Bird Sales & Eng. Corp.	755
New Departure, Division of General Motors	3rd cover
New Holland Machine Co.	698
New Idea Farm Equipment Co.	743
The New York Air Brake Co.	694
Portland Cement Assn.	755
Purolator Products, Inc.	687
Reynolds Metals Co.	745
E. B. Sewall Mfg. Co.	753
Stephens-Adamson Mfg. Co.	749
Stow Mfg. Co.	751
The Texas Co.	741
Timken Roller Bearing Co.	4th cover
The Torrington Co.	683
Unitcast Corp., Steel Castings Div.	752
U.S. Steel Corp.	699, 737
Upson-Walton Co.	746
Vickers, Inc.	697
Wisconsin Motor Corp.	750
Young Radiator Co.	688

Professional Directory

RATES: 80 cents per line per issue; 40 cents per line to ASAE members. Minimum charge, five-line basis. Uniform style setup. Copy must be received by first of month of publication.

FRANK J. ZINK
Agricultural Engineering Service
Development - Design - Research - Markets
Public Relations
BOARD OF TRADE BLDG., CHICAGO 4, ILL.
Tel. HArrison 7-0722

J. F. SCHAFFHAUSEN
Agricultural & Sales Engineering
Research Farms: United States - Canada
Market Development, Sales Training,
Design, Public Relations, Editorial Services
IRVINGTON-ON-HUDSON, NEW YORK

COPIES AVAILABLE
AGRICULTURAL ENGINEERS YEARBOOK
Contents includes (1) ASAE-Approved Standards, Recommendations, and Engineering Data; (2) Directory of Suppliers to Agricultural Engineers; (3) Roster of ASAE Members; (4) List of ASAE Officers, Divisions, Sections, and Committees. Published by the American Society of Agricultural Engineers, this publication is an essential and frequently consulted reference source for every agricultural engineer, as well as for any individual, organization, or library in need of the particular information it contains.
Copies of the current edition of AGRICULTURAL ENGINEERS YEARBOOK are available at $5.00 per copy postpaid. Send order with remittance to
American Society of Agricultural Engineers
St. Joseph, Michigan

John Deere chooses New Departure

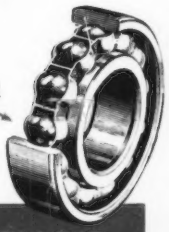
. . . for the PICK OF THE CROP

Profits up—costs down! John Deere's new No. 1 Cotton Picker does the work of 40 men! But savings aren't confined to labor. For this picker saves *importantly* on upkeep, too. Its 52 New Departure **ball** bearings in 13 locations need no time out for either lubrication or adjustments.

With New Departure **ball** bearings used in so many important positions, positive and accurate location of parts is assured . . . and that means a machine always in top operating condition . . . always ready to do the job *fast* and *right*.

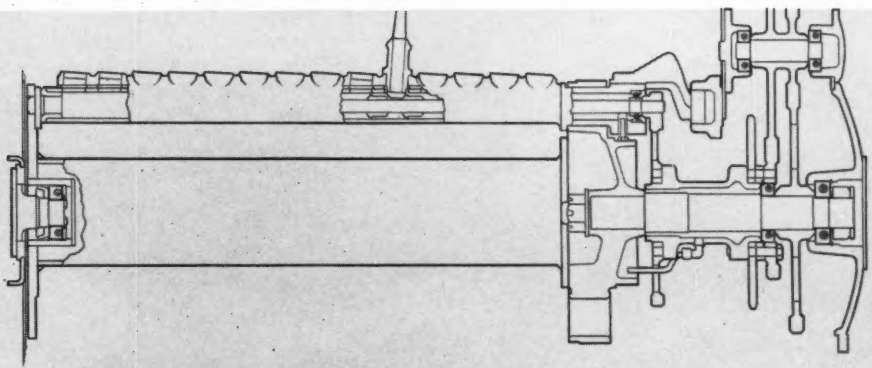
If *you're* designing for the farm, it will pay you to learn the advantages of New Departure *ball* bearings. Talk with your New Departure engineer about it—*today!*

NOTHING ROLLS LIKE A BALL



NEW DEPARTURE
BALL BEARINGS

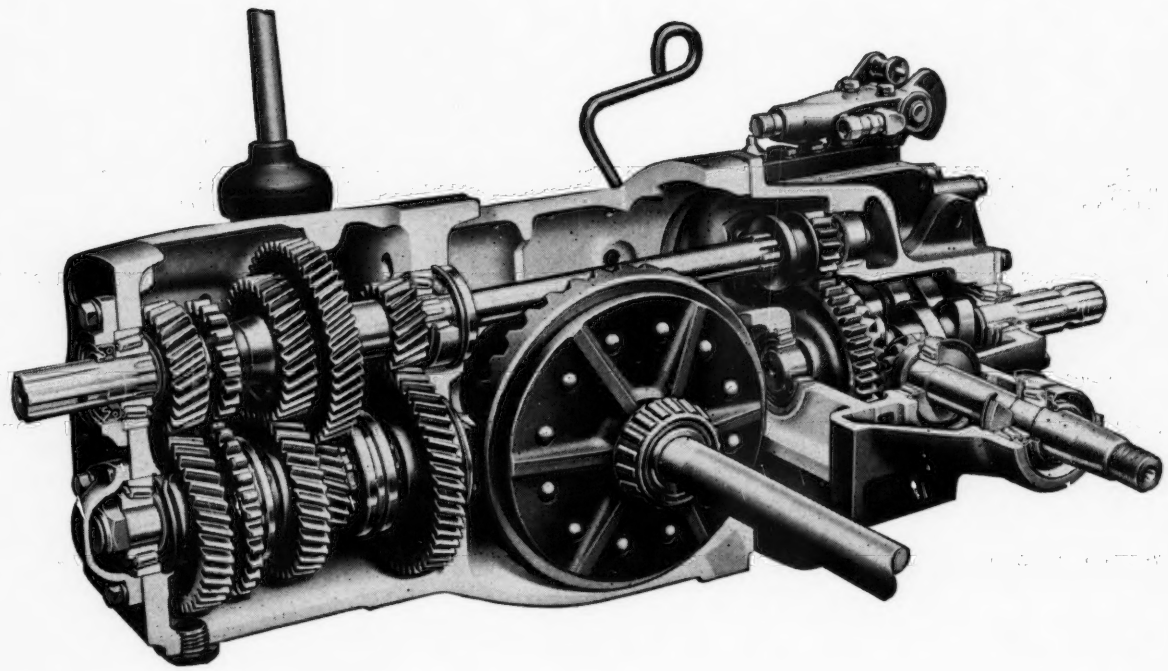
NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT
Plants also in Meriden, Connecticut, and Sandusky, Ohio
In Canada: McKinnon Industries, Ltd., St. Catharines, Ontario



Cutaway shows six of the 17 New Departure **ball** bearings in the rear picker drum of John Deere's No. 1, One Row Mounted Cotton Picker. These bearings preserve precision alignment, need no upkeep.

EVERY MAKE OF FARM TRACTOR HAS TIMKEN BEARINGS; MORE AND MORE IMPLEMENTS ARE USING THEM, TOO!

How Allis-Chalmers Engineers Get Maximum Shaft Rigidity, Proper Gear Contact in "CA" Tractor Transmission



THIS cutaway drawing of the Allis-Chalmers "CA" tractor transmission shows the power take-off shaft, bevel gears and transmission shafts mounted on Timken® tapered roller bearings.

Allis-Chalmers engineers selected Timken bearings because they assure maximum rigidity under load and thereby provide ideal gear contacts. Result: longer gear life, less chance of trouble.

Timken bearings provide greater shaft rigidity because they carry the load on full lines of contact between rollers and races. This full line contact also gives them inherently high load-carrying capacity. Furthermore their tapered design enables them to take any combination of radial and thrust loads. With Timken bearings no extra devices are needed to carry the thrust of the bevel gears.

Timken bearings in the transmissions also reduce the cost of machining the housing. The taper construction permits a simple and positive bearing adjustment at the time of assembly and after long periods of service.

Timken bearings solve three big problems for agricultural engineers. 1. They handle combination loads. 2. They make closures more effective because they keep shafts concentric with housings. 3. They make equipment operate easier because they are designed to have true rolling motion and manufactured to live up to their design.

Write now for helpful booklet "Tapered Roller Bearing Practice in Current Farm Machinery Applications". The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

The farmer's assurance of better design

Tapered Roller
TIMKEN BEARING
EQUIPPED

NOT JUST A BALL ○ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER ⬭ BEARING TAKES RADIAL ↓ AND THRUST →○← LOADS OR ANY COMBINATION